REPORT NO.
TDR-930(2701-01)TN-1
Part I, No. 7

Applied Research Management

Abstract Bulletin

(Part I)

Abstracts 1-1203 through 1-1325

JANUARY 1962

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Prepared for DEPUTY COMMANDER AEROSPACE SYSTEMS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Inglewood, California

AEROSPACE CORPORATION
CONTRACT NO. AF 04(647)-930

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ABSTRACT BULLETIN

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ABSTRACT

Part I, No. 7 is a bibliography, with abstracts, from unclassified literature presented on the subject of Flight Vehicle Power. Selected references in the fields of materials and weapon fire control are also included. All references are to primary sources.

Approved by K. B. Andrews
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Literature Research Group

AEROSPACE CORPORATION
El Segundo, California

ACKNOWLEDGEMENT

The information included in this volume was prepared by K. B. Andrews, N. B. Crow, M. S. Hicks, and K. N. Trirogoff.

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I. FLIGHT VEHICLE POWER

SECTION A - GENERAL

1-1203. DEVELOPMENT OF A HIGH-TEMPERATURE, NUCLEAR-RADIATION-RESISTANT PNEUMATIC POWER SYSTEM FOR FLIGHT VEHICLES. General Dynamics/Convair, San Diego, Calif., Rept. no. ZR-1001-11. 24 Dec. 1961. 82p. Contract: AF 33(616)-7582. A62-369.

During this reporting period contracts were awarded for development of the rotary actuator and servo valve, pressure regulator, relief valve, accumulator, filter, and check valve. The development status of these components and the turbo-compressor is discussed in this report. Progress was made on refining the test program for the tube fittings and boss seals. All test parts have been ordered and some were received by Convair. A high-temperature facilities survey was undertaken to evaluate instrumentation, procedures, and safety regulations used by other companies concerned with high-temperature and nuclear radiation testing. Results of this survey are also included in this report. Initial preparations were undertaken to prepare Convair's High Temperature Test Laboratory for the test phase. Modification of the environmental chamber and air heater are underway. Instrumentation requirements have been reviewed and preliminary procurement was initiated on long lead time test equipment. The work accomplished during this reporting period lays the groundwork for individual component and subsequent system testing.

1-1204. DEVELOPMENT OF THE POWER SUPPLY OF THE TRANSIT SATELLITE. W. C. Scott. Johns Hopkins Univ., Silver Springs, Md. Applied Physics Lab., Rept. no. CM-986. Dec. 1960. 54p. illus. Contract: NOrd 7386. A62-165.

Project Transit is the code name of a program aimed at achieving a world-wide, all-weather navigation system. The system is based on the fact that the orbital parameters of an earth satellite can be determined by analyzing the doppler frequency shift in radio frequency signals transmitted by the satellite. Conversely, if the orbital parameters are known, an observer's location can be accurately determined. This report covers the development of the Transit Navigation Satellite power system and deals with the silicon photovoltaic converters, the rechargeable nickel-cadmium batteries, the zinc-silver oxide batteries used in an early version, and the static conversion equipment. The requirements and test conditions are discussed with data presented which summarizes the telemetered data from the orbiting vehicles.

1-1205. ELECTRIC POWER GENERATION BY THERMALLY ACTIVATED CERAMIC-METAL COMBINATIONS (THE AUSTIN EFFECT). Westinghouse Electric Corp., Lima, Ohio. Aircraft Equipment Dept. (no rept. no.). Oct. 1960. 18p. A61-11559.

A new method of electric power generation utilizing thermally activated ceramic-metal combinations is now feasible. This phenomenon is identified in this document as the Austin Effect and those devices which exhibit this effect are referred to as Austin cells. The Austin Effect is exhibited when the cell is heated to its operating temperature. A temperature differential is not required for operation as in thermoelectric and thermionic devices. Present operating temperatures are in the range above 250° C. Preliminary test data indicate that it may be possible to operate this Austin cell up to 2000° C or higher. Due to its simplicity and the nature of its materials, the Austin cell is inherently highly reliable, inexpensive to produce, and has a long shelf life. Devices based on this principle appear extremely attractive as power supplies in high temperature applications, especially at temperatures where conventional power supplies are destroyed or inoperative. Some possible applications are: 1) electrical power as a result of waste heat by integrating Austin cells into rocket nozzle structure; 2) power source during missile nose cone reentry, activated by reentry heat; 3) ablation indicator on reentry type vehicles such as Mercury and Dyna-Soar; and 4) power source (cont.)

1-1205. (Cont.)

for remotely located temperature indicators. This document discusses the discovery of the Austin Effect, some of the preliminary work accomplished to date, and several possible applications for the Austin cell.

1-1206. SPACECRAFT RADIATORS. Space/Aeronautics, vol. 37, no. 1, Jan. 1962, p. 76-82.

This article reviews the data and methods available to the designer of active low-temperature radiators for spacecraft as he copes with the problems of meteoroid protection, fluid and coating selection, and minimum weight. Materials parameters are covered in detail, and several basic design procedures are outlined.

1-1207. VOLTAGE REGULATION AND POWER STABILITY IN UNCONVENTIONAL ELECTRICAL GENERATOR SYSTEMS. Quarterly Progress Report no. 2, 30 Sept.-31 Dec. 1961. General Electric Co. Aircraft Accessory Turbine Dept., West Lynn, Mass. 31 Dec. 1960. 89p. Contract: NOw 60-0824-C. A62-169.

The purpose of this study is to investigate the system problems connected with the use of static external voltage converters and regulators and unconventional power sources, to determine the most desirable systems to use, and to establish the performance characteristics of these systems. The overall purpose is satisfied by contributions from three areas of activity: 1) Methods of internal control of electrical source voltage are being determined and evaluated. In the process, static and dynamic behavior of the sources is being determined. 2) Optimum external voltage regulator and converter circuits for use with unconventional power sources are being determined and evaluated. 3) System performance characteristics are being determined by a combination of the external voltage regulator and converter characteristics with the characteristics of the power sources. The resultant system characteristics will allow selection of the optimum system for any given application. Quantitative data giving fuel cell static volt-ampere characteristics and an estimate of the fuel cell equivalent

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1-1207. (Cont.)

circuit are given. An analysis of the use of voltage sensitive parasitic loads to control the output voltage of a power source is presented. A discussion and analysis of static inversion techniques is included.

SECTION B - CHEMICAL SOURCES OF ENERGY

1-1208. AN ANALYSIS OF POWER DISTRIBUTION RELATIVE TO THE DESIGN OF HIGH ENERGY DENSITY BATTERIES. William C. Spindler. Naval Ordnance Lab., Corona, Calif., NAVWEPS Rept. no. 7184. 15 July 1961. 24p. AD 260 002. A61-11018.

In the design of special purpose batteries for applications in which weight and power are critical factors, a study of power efficiency, as well as energy efficiency, is necessary. There are major differences in the requirements for transferring energy in 10 minutes or 10 months. High power efficiency requires large generator losses and temperature rises, which are equivalent to poor utilization of active ingredients and low energy efficiency. Important aspects of power distribution between a generator and its load for high-energy, rapid power transfer are analyzed. General equations are developed for the basic ohmic circuit and are illustrated for a 1200-watt battery application. Transfer efficiencies are examined, and an optimum power transfer point is defined at approximately half the current density required for maximum load power. The effects of polarization characteristics on maximum power transfer are briefly discussed. The rate at which energy can be transferred electronically through ohmic circuits is subject to much lower theoretical limits than appear to have been recognized. There is a 25% maximum limit on energy transfer for purely ohmic linear polarization,

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1-1208. (Cont.)

decreasing as nonohmic polarization increases. Generator polarization functions of second of higher order will permit higher theoretical efficiency of power transfer--ok to 100%.

1-1209. DESIGN STUDY OF LONG DURATION LOW POWER CHEMICALLY FUELED POWER SUPPLY WITH INTEGRATED THERMAL CONTROL. R. Bailey, R. Barber, et al. Interim Progress Report no. 9, 1 Aug.-31 Oct. 1961. Sundstrand Aviation-Denver, Rept. no. CDRD-61:3023. 15 Nov. 1961. 247p. illus. Contract: AF 33(616)-6421, Proj. no. 3145, Task no. 30328. A61-11402.

An interim report for the design study of a long-duration, low-power, chemically fueled power supply for space vehicles is presented. This is the fourth such report since the program was redirected from a closed cycle to a thermally integrated open cycle machine. The redirected program goals are to design, develop, and test an eight shaft horsepower FVPU system for a 300-hr mission fueled by liquid hydrogen and liquid oxygen with a specific propellant consumption less than 1.5 lb per shaft horsepower hour. Shaft energy supplied to a direct driven alternator will be consumed by accessories and a load; this energy will then be returned to the turbine working fluid as cycle heat input. This interim progress report represents the accomplishments to date toward a completed power supply to be delivered for flight testing in a zero gravity facility airplane. The bulk of all parts have been manufactured and delivered to the appropriate system or subsystem test location. The ball bearing rotating assembly system for initial (cont.)

1-1209. (Cont.)

system shakedown, which includes all of the thermally integrated system components, is being assembled for test in the Sundstrand Pacoima altitude facility. The gas bearing test rig for developing the prototype gas bearings has been assembled and tests initiated at Sundstrand Aviation-Denver. The prototype alternator is being performance calibrated at Sundstrand Aviation-Denver. Upon completion of these three phases of system and subsystem testing, the gas bearings will be incorporated into the rotating assembly for system performance proof and endurance operation.

1-1210. **FLAT CELL MAGNESIUM DRY CELL BATTERIES.** F. A. Keller. Fifth Semiannual Progress Report, 1 Apr.-1 Oct. 1961. Bright Star Industries, Clifton, N. J. 16p. Contract: DA-36-039-SC-78231. A62-1271.

Work was concentrated on production of a low resistance duplex electrode. Storage life tests indicated that there was difficulty in obtaining sealing; electrolyte was leaking and causing corrosion.

1-1211. **FUEL CELL MATERIALS.** H. P. Gregor. Second Quarterly Progress Report, 1 Dec. 1960-28 Feb. 1961. Army Signal Engineering Labs., Fort Monmouth, N. J. 18p. Contract: DA-36-039-SC-85384. AD 262 528. A62-170.

An improved cell for the measurement of the ohmic resistance of fuel cell electrolytes was designed. Work is being carried forward on improved homogeneous- and heterogeneous-type membranes having catalysts incorporated into their faces. Cells for measuring the functional behavior of membranes in mixtures of organic liquid fuels and water have been designed and are under construction.

1-1212. **FUEL CELLS--WHERE ARE WE NOW?** Industrial and Engineering Chemistry, vol. 54, no. 1, Jan. 1962, p. 65-8.

This is primarily a report on the prospects for use of fuel cells in surface-based power systems. Some material about the electrochemistry of the fuel cell is presented.

1-1213. **INVESTIGATION OF AgO PRIMARY BATTERIES.** Final Report, 1 June 1959-31 Aug. 1961. Electric Storage Battery Co., Raleigh, North Carolina. Missile Battery Div., Rept. no. E-30-61. 8 Sept. 1961. 110p. illus. Contract: DA-36-039-SC-78319, Proj. no. 3C18-03-001. A61-11729.

The electrochemical mechanism of power production in the silver-zinc cell is discussed in this report. Details of the evaluation of various types of electrodes are presented. Experiments were conducted with laboratory test batteries to determine the mechanical and electrical characteristics of the cells, the best type of separator, and solubility of Ag_2O and AgO in the KOH electrolyte. The contractor evaluates four types of zinc-silver batteries: 1) the button-type cell used in hearing aids; 2) two research cells, the second type using electroformed porous metallic silver anodes and a proprietary pressed zinc cathode; and 3) a production version of the second research cell. The production cell has the porous metallic silver anodes and the pressed zinc cathode, and closely follows the design of the laboratory cell except that less silver and more zinc is used. The average room temperature capacity of the production cells is 15 amp-hrs for a positive electrode theoretical efficiency of 70% and a negative electrode theoretical efficiency of 52%. The negative electrode is limiting efficiency, and further studies are to be made to find out why and how the limitation may be corrected.

1-1214. INVESTIGATIVE STUDY RELATING TO FUEL CELLS. Progress Report no. 5, 26 Apr.-25 Aug. 1961. California Research Corp., Richmond, Calif. 27 Oct. 1961. 47p. Contract: DA-49-186-ORD-929. A62-1272.

This is a progress report on a study of the chemical reaction mechanisms and kinetics of fuel half-cell electrodes. Such petroleum-derived fuels as propane were studied. The hydrogen fuel cell is used as a reference. Erratic behavior of the fuel cell gave considerable difficulty, which was found to be due largely to poisoning, principally by air and materials leached from the ion exchange membrane separators. This was more important with petroleum fuels than with such highly reactive fuels as hydrogen. Gaseous hydrocarbons were the most active petroleum-based fuels. When the current is kept below a certain threshold value, prolonged operation is possible with very gradual polarization; a rapid loss of activity occurs when the threshold is exceeded. The rate of recovery of open circuit potential after operation under load is more rapid with more reactive fuels and at higher temperatures. The rates of fuel and diffusion of oxidation products at the electrodes is rapid enough to support practical current densities. Results of studies of the chemical kinetics and reactions at the electrodes of the fuel cell are presented.

1-1215. ION-EXCHANGE MEMBRANE FUEL CELL DEVELOPED FOR SPACE VEHICLES. R. H. Blackmer and G. A. Phillips. S.A.E. Journal, vol. 70, no. 1, Jan. 1962, p. 82-6.

An experimental ion-exchange membrane fuel cell is being developed for use in a wide range of space vehicles. A 9-cell demonstration battery has been constructed using conductively cooled cells; it is now undergoing laboratory evaluation. The heart of this fuel cell is an ion-exchange electrolyte, which is a reinforced polymer membrane; acidic polymers have been most successful to date. A thin catalytic electrode is applied to each surface of the membrane to provide a large number of reaction sites per unit area. The complete assembly is relatively tough and pliable. Electrons are conducted away from the catalytic electrode surfaces by ribbed metallic bipolar electron collectors. Static heads of hydrogen and oxygen are supplied to the anodic and the cathodic sides of the cell, respectively. When the circuit is closed, electrochemical reactions will cause current to flow. From 34-70% of the heat of the reaction of hydrogen and oxygen can be realized as useful electric energy. The construction of the demonstration fuel cell is described in detail. There is considerable possibility of corrosion at the contact between electron collector and membrane; titanium and some stainless steels have worked well. Two heat transfer systems have been used: 1) internal forced convection cooling of the membranes with removal of the heat to a

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1-1215. (Cont.)

remote radiator, and 2) conduction of the heat to the edge of the electron collectors, with removal from this point to a remote radiator. An experimental battery for orbiting tests is described. It is heavy and bulky and must be considered as a prototype. An experimental program has established that the ion-membrane fuel cell will operate without gravity forces, and provides design data for all elements of a passive water removal and storage system.

1-1216. **RELIABILITY STUDY--HIGH RATE LECLANCHE WAFER CELLS.** Martin Sulkes. First Annual Report, 1 Mar. 1960-15 Apr. 1961. United States Electric Mfg. Corp., New York City, N. Y. 63p. illus. Contract: DA-36-039-SC-85266, Task no. 3G 18-03-001-01. A61-9877.

The report describes the fabrication and evaluation of Leclanche wafer-type dry-cell batteries. Tests were made under high rate discharge in temperatures ranging from -20° F to 113° F. Initial test data is presented for 17 groups of units of various sizes and voltages. Many of the failures were due primarily to faulty internal seals. It is felt that an improvement in capacity would be made by using a slightly larger wafer cell. Production of wafer batteries with large numbers of cells connected in parallel will be prohibitive in cost unless the process is partially mechanized. The advantages of this battery are partially offset by the problems of maintaining good intercell contacts.

SECTION C - MAGNETOHYDRODYNAMIC SYSTEMS

1-1217. **STUDY OF ELECTRICAL ENERGY CONVERSION SYSTEMS.** Arthur Sherman, G. W. Sutton, et al. General Electric Co. Missile and Space Vehicle Dept., Philadelphia, ASD TR 61-379. Sept. 1961. 107p. Contract: AF 33(616)-7539, Proj. no. 3145, Task no. 61098. A62-1178.

A number of theoretical and experimental investigations have been carried out to investigate MHD and EHD power generation. The theoretical studies have included analysis of both optimum channel configuration, and optimum initial conditions for an MHD generator, as well as an analysis of the performance of an idealized EHD generator. The experimental studies centered largely on non-equilibrium ionization experiments using a plasma jet as a source of high temperature gas. Finally, some calculations have been carried out for the constant velocity MHD generator performance, and the investigation of an oxy-cyanogen MHD generator has begun. This report covers the theoretical, experimental and systems studies performed on magnetohydrodynamic generators and consists of the following papers: Optimum Configuration for an MHD Generator with Variable Electrical Conductivity, by John Von Iwaarden and George W. Sutton; Optimum Inlet Conditions for Open Cycle Reaction MHD Generators, by G. W. Sutton; Boundary Layer studies, by Arthur Sherman; Theoretical Study of the Electrohydrodynamic Generator, by John M. Smith; Preliminary Results of (cont.)

1-1217. (Cont.)

Experiments on Non-Equilibrium Ionization in an MHD Generator, by F. A. Robben; Design and Initial Tests of Equipment for Measuring Non-Equilibrium Ionization, by F. Millheim; Progress on Plasma Drag Balance, by Terrance Flaherty; Performance Calculations for Reaction MHD Generators, by Sheldon Blecher; Performance of Oxy-Cyanogen MHD Generators by Arthur Sherman.

1-1218. **THEORETICAL PERFORMANCE ANALYSIS OF A CONSTANT VELOCITY MHD GENERATOR FOR COMBUSTION PRODUCTS OF HYDROCARBON AND AIR.** Sheldon Blecher. General Electric Co. Missile and Space Vehicle Dept., Philadelphia, ASD TR 61-190. Oct. 1961. 209p. illus. Contract: AF 33(616)-7539. A62-1181.

Performance calculations for a magnetohydrodynamic generator using hydrocarbon-air combustion products are presented. To make the gas conducting without exceeding temperature limits imposed by materials, it is necessary to seed the gas with either potassium or cesium. Since this would be an open-cycle system, the high cost of cesium would make the use of potassium necessary. The combustion product gas is assumed to be in thermal equilibrium and representable by a Boltzman distribution so that the degree of ionization can be determined by means of the Saha equation. Variations in pressure, temperature, gaseous electrical conductivity, density, entropy, enthalpy, number density, degree of ionization, and Hall effect as a function of channel length are shown graphically, Improved generator performance can be achieved by an increase in gas velocity for a fixed channel length, and by increasing the magnetic field strength.

SECTION D - MECHANICAL DEVICES

1-1219. **A DESIGN STUDY OF A SMALL HOMOPOLAR MOTOR.** George J. Bukow. Massachusetts Inst. of Tech., Cambridge. Research Lab. of Electronics. Energy Conversion Group, Rept. no. DSR 7672; ASD TR 61-101. Jan. 1961. 46p. Contract: AF 33(616)-7624. 44 refs. A61-11013.

Homopolar machines are so named because the conductors always cut lines of unidirectional flux and give a continuous one-directional electromotive force without the use of commutators. Homopolar machines were developed around the turn of the century, but commutator machines were much more adaptable to modern technology and development ceased. Research work currently in progress is aimed at thermoelectric energy conversion to produce d-c currents of 1000 amps at voltages of 1 volt or less. The homopolar motor seems well adapted to convert electric power of this character into mechanical energy. Previous homopolar motors have used metal brushes with voltage drops too high to be acceptable. Better efficiency has been obtained by use of liquid metal brushes in large homopolar generators. A discussion of the theory of brush contact is presented, and the optimum characteristics of liquid metal brushes are developed. Experiments with a mercury brush indicate that this could be used to conduct high currents at very low voltage drops without excessive hydraulic friction. A theoretical design minimizing the total power loss in the motor is presented. With a

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design output of 1 kw at 900 rpm, the voltage rating is 0.450 volts, and current rating is 2340 amperes; an efficiency of 84% is predicted.

SECTION E - NUCLEAR SOURCES OF ENERGY

1-1220. INVESTIGATION OF REENTRY DESTRUCTION OF NUCLEAR AUXILIARY POWERPLANT. Avco Mfg. Corp. Research and Advanced Development Div., Wilmington, Mass., TR-61-69. RAD TR-61-28. Oct. 1961. 366p. Contract: AF 33(616)-7530, Proj. no. 1831, Task no. 183101. A62-898.

This work has been undertaken to determine how the re-entry of a nuclear reactor from orbit can be made inherently harmless by the re-entry environment alone and without the use of fallible components. Accordingly, the problems involved in the re-entry destruction of a nuclear reactor--fuel-element exposure, meltdown of the fuel elements, dispersal of the molten residue, and combustion of the molten residue--have been investigated by theoretical and experimental techniques. Results of this study indicate that without modification, flight models of the August 1960 developmental reactor-vehicle systems will not be reduced to a harmless residue by the re-entry environment. However, the parametric and design studies are relatively general, and they may be useful to designers in developing this and other reactor-vehicle systems for safe re-entry. Four appendices deal with the separate aspects of the re-entry sequence for destruction of the SNAP system, and the fifth, with flight test recommendations. Although the preparation of a complete flight test design is beyond the scope of the present work, detailed recommendations for a flight test program to prove the safety of a reactor designed for re-entry destruction have been presented.

1-1221. REENTRY AND DISPOSAL PHENOMENA FOR NUCLEAR AUXILIARY POWER SYSTEMS. First Quarterly Report. General Dynamics/Astronautics, San Diego, Rept. no. AE62-0032. 31 Dec. 1961. 15p. Contract: AF 29(601)-4893, Proj. no. 1831, Task no. 183101. A62-1022.

This report contains a description of the organization set up to: 1) work on the problem of reentry and disposal of nuclear flight vehicle power systems, and 2) to evaluate technically this work and work done by other contractors. Progress reports are included on the following topics: 1) Atmospheric data of value to this program have been compiled and presented graphically. 2) The effect of fast-neutron-produced interstitial helium nuclei on breakup of beryllium reactor reflectors has been studied and found to be insignificant. 3) Studies of the fallout hazard from reentry fuel elements has been studied, and it has been found that the number of particles at ground level is a simple function of particle size and altitude of release. Brief discussions of other work both in the preliminary and projected stages are given. A literature survey of documents pertinent to the project was made at Kirtland AFB. 350 documents have been chosen; a list of titles and a classified, limited-access bibliography are being prepared.

1-1222. SOME NOTES ON THERMONUCLEAR REACTORS.
G. Martelli. Nuovo Cimento Supplemento, vol. 19, no. 10, 1 Nov. 1961, p. 67-82.

Methods of confining plasma generated in a thermonuclear reactor are the primary concern in this paper. Any reactor using magnetic confinement must satisfy certain general requirements. First, the rate of energy release must exceed the rate of energy loss from the plasma. Thermonuclear reactions are possible only above a critical temperature. Second, in order for a thermonuclear reactor to be self-sustaining, the released energy must exceed the energy supplied to produce the hot plasma. There are two principal methods of obtaining a hot plasma: 1) by ionizing a cold gas and raising its temperature to thermonuclear range, and 2) by accumulating hot particles in a trap until they build up a plasma. There is a widespread belief that economic reactors can be designed only on the basis of a steady-state or quasi-stationary device, and hence the achievement of long periods of plasma confinement in traps is required for reactor control. Recently it has been suggested that if long term confinement cannot be achieved, fusion reactors where the plasma is not confined could still be operated. The mechanism might be compared to that of a miniature H-bomb, where a magnetically driven plasma shell would generate the interacting plasma column and the power output would be absorbed by the laboratory apparatus. The remainder (cont.)

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of the paper is devoted to a discussion of methods of confining the plasma. Stabilized pinch discharges can be obtained by use of an external longitudinal magnetic field and use of metal sheeting around the discharge chamber. Experimental data demonstrating the development of a plasma column are discussed. Stellerators have been used to study nonturbulent confined plasma; although plasma confinement is poor, stability has been achieved. Methods of high frequency heating of plasma in stellerators are being developed. The main task appears to be achievement of a steady hot plasma. Magnetic mirrors can be used also to confine plasmas, and experimental data show that the technique has been successful. The gas should be completely ionized and the amount of adsorbed matter in the walls should be negligible. Methods of heating the plasma are discussed. Relativistic electrons have been used to confine and heat plasmas. Electrons are injected into magnetic mirrors and form a cylindrical sheet; when the current reaches high enough values, the direction of the magnetic field in the central region reverses and a pattern of closed lines of force is created, providing an effective method of confining the plasma.

1-1223. ZIRCONIUM-URANIUM COMBUSTION STUDY. Report no. 1, for December 1961. Stanford Research Inst., Menlo Park, Calif. 15 Jan. 1962. 3p. Contract: AF 29(601)-4954, Proj. no. 1831, Task no. 79512. A62-927.

Nuclear flight vehicle power systems, intended for use in aerospace vehicles, present a problem of disposal at the end of their projected flight. A practical means of safe disposal is incineration during reentry. This is a progress report of a study of the combustion of uranium-zirconium alloy under simulated reentry conditions, particularly stagnation rates and pressures. It describes the experimental apparatus set up to study the problem, consisting of an arc-image furnace as a source of radiant energy, a glass sample holder to permit observation, and a motion-picture camera to supplement visual observation. Preliminary calibration work is to be carried out.

SECTION F - SOLAR SOURCES OF ENERGY

1-1224. CHEMICAL REACTIONS TO CONVERT SOLAR ENERGY INTO POWER SOURCES. J. J. Rowlette. Electro-Optical Systems, Inc., Pasadena, Calif., Rept. no. ARL 60. Sept. 1961. 44p. illus. Contract: AF 33(616)-6546, Proj. no. 7117, Task no. 70349. 31 refs. A62-748.

Photochemical synthesis of hydrogen peroxide and the combined thermal-photochemical decomposition of sulfur trioxide were the goals of the program described here. The interest in these studies lies in the ultimate possibility of using sunlight for regenerative electrolytic cells, or for the purpose of making hydrogen peroxide for other high energy applications. A theoretical examination given in this report indicates the possibility of achieving conversion efficiencies higher than those obtainable by any present device, although only some very general outlines of an approach to the problem are apparent at this time. A rather careful theoretical analysis of the photolysis and thermal decomposition of sulfur trioxide strongly indicated that a combination of a photochemical and thermal decomposition would not yield a decomposition greater than the two processes used separately. For this reason, the experimental work was limited completely to the photochemical synthesis of hydrogen peroxide. Hydrogen peroxide synthesis was accomplished in both liquid and gaseous states using cadmium telluride and zinc oxide as photocatalysts in each case. In the absence of organic additives in the liquid

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phase, neither catalyst shows any promise. In the presence of the additives, quantum efficiencies are quite high under some circumstances but the reactions are always exothermic and consequently of no value for energy conversion. However, it was found that the reaction could be performed in the gas phase in a flow system using solid photosensitizers. These reactions are almost certainly endothermic and therefore represent energy conversion.

1-1225. CLOSED CYCLE SPACE SOLAR POWER PLANT WEIGHT OPTIMIZATION. P. J. Berenson. Contributed by the Solar Energy Applications Committee for presentation at the Winter Annual Meeting, New York, 26 Nov.-1 Dec. 1961, of The American Society of Mechanical Engineers. 8p. ASME 61-WA-159.

A possible scheme for a closed-cycle solar power plant is presented in this paper. The power system includes the following components: solar collector, absorber (heat source and energy storage), radiator (heat sink), turbogenerator, pump, control and guidance equipment, and structure. Most of the weight is contained in the collector, absorber, and radiator. The purpose of this paper is to develop an analytical method for minimizing the total weight of these three components. In particular, equations for the preliminary selection of the optimum source (absorber) and sink (radiator) temperature are developed. The results applied to an earth satellite indicate that the weight and size of the major components are acceptable. No single power-plant parameter appears limiting. The important variables appear in groups, allowing one to compromise the value of one with respect to another while maintaining constant net performance. The minimum absorber-surface area may be limited by two factors: the maximum heat-transfer rate per unit area which can be transferred to the interior of the heat source, or the

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1-1225. (Cont.)

ability of the solar collector to concentrate and focus the energy it intercepts. The minimum area allowed by each of these considerations must be calculated for each set of conditions. The largest of the two minimum areas establishes the absorber area.

I-1226. ENERGY BALANCES ON A PARABOLIC CYLINDER SOLAR COLLECTOR. G. O. G. Lof, D. A. Fester, and J. A. Duffie. Trans. Amer. Soc. Mech. Engrs.: Pt. A., J. Eng. for Power, vol. 84, no. 1, Jan. 1962, p. 24-32.

A technique for optimizing the design of focusing solar collectors was developed through a detailed study of the energy balances for a parabolic-cylindrical reflector with tubular receivers of three diameters. Experimental data for concentration ratios of 10-22.5 and surface temperatures of 88-353° F are presented. Receiver temperature, meteorological variables, and distribution of reflected radiation in the focal zone of the reflector were measured and correlated so as to permit optimization of the concentration ratio. Collection efficiencies and receiver radii for optimum performance are 51% at 1.10 in., 40% at 0.90 in., and 25% at 0.80 in. for average receiver surface temperatures of 210, 275, and 345° F.

I-1227. HIGH EFFICIENCY SILICON SOLAR CELLS. Pierre Lamond and Alexander J. Oszy. First Semiannual Technical Summary Report, 18 Sept.-31 Dec. 1959. Transitron Electronic Corp., Wakefield, Mass. 20p. illus. Contract: DA-36-039-SC-85250, Task no. 3A99-09-001-03, ARPA order no. 80-59. AD 232 807. A61-8433.

The objective of this contract is to conduct research investigations leading to the improvement of the practical efficiency of silicon solar cells to 12% or higher. This program also includes studies of methods that will result in high yields and techniques that will permit mass production of these more efficient cells at the lowest possible cost for a 1x2 cm cell. An investigation of the factors limiting the efficiency of solar cells has been started. The contact resistance and the reflection losses at the silicon surface were both studied. The contact resistance was found to be less than 0.09 ohm on the p side and even smaller on the n side. In order to reduce reflection losses at the silicon surface, anti-reflection coatings have been developed to apply to the silicon surface. The results obtained with two such coatings, i.e., silicon monoxide and magnesium fluoride are discussed.

1-1228. INVESTIGATION OF SINGLE ENERGY GAP SOLAR CELL MATERIAL. Robert J. Robinson. Technical Summary Report no. 2, 1 Jan.-30 June 1961. Illinois Inst. of Tech., Chicago. Armour Research Foundation, Rept. no. ARF 1175-10. 33p. Contract: DA-36-039-SC-87381, ARPA Order no. 80-61. AD 263 861. A62-168.

The principal purpose of the program to make a high temperature solar cell with better characteristics than can be expected from silicon is discussed and the main reasons for choosing CdTe are listed. The early state-of-the-art of this material determined the nature of the program and during the first year emphasis was on crystal growth studies. The many steps from elemental cadmium and elemental tellurium to a completed CdTe solar cell are listed. This report starts with step III, zone leveling CdTe, and proceeds section by section to discuss the development of techniques for slicing, lapping, polishing, chemical etching, chemical junction formation, vapor diffusion junction formation, electroding and mounting on crystal holders. The multi-zone furnace for fabrication vapor diffusion junction is pictured with its accessory equipment for fabricating diffusion junctions in compound semiconductors. The advantage of versatility in fabrication procedures for early-state-of-the-art compound semiconductors is pointed out. Electrical, thermal, and optical experiments on the n-type base material are described, and the

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optical transmission of the n-type CdTe material shows a slope for absorption versus wavelength more similar to silicon than to GaAs or InP. Current emphasis is on forming p-type layers on n-type CdTe by vapor diffusion of silver under a survey of conditions. It is shown that 500° C fabrication is possible and that both shallow and deep junctions can be formed. Spectral response curves of silicon, chemical junction CdTe, diffusion junction CdTe are given and discussed. Preliminary high temperature photovoltaic measurements tend to confirm CdTe for high temperature solar use.

1-1229. IRRADIATION OF BARE SILICON SOLAR CELLS. T. H. Clarke and D. H. Tompkins. Presented at the American Institute of Electrical Engineers Winter General Meeting, New York, 29 Jan.-3 Feb. 1961. 4p. AIEE paper no. CP 61-283.

The General Electric Co. has conducted experimental investigation of the effect of electron bombardment on 8% silicon solar cells at various energy ranges from 1.2 mev to 2.0 mev. A 2 mev Van De Grauf machine at High Voltage Engineering Corp., Burlington, Mass., was used. The following conditions were used: Electron energy in mev: 1.2, 1.4, 1.6, 1.8, 2.0; Dosage in Electrons/cm^2: 1×10^{15}, 3×10^{15}, 6×10^{15}, 10×10^{15}. This paper describes the testing apparatus used and an analysis of the results with the curves obtained from the data taken. Calculations using range energy curves predict that 1.7 mev electron striking cells after passing through 50 mils of glass should be equivalent to 1.2 mev electrons incident on bare cells.

1-1230. PERFORMANCE OF SILICON SOLAR CELLS AT HIGH LEVELS OF SOLAR RADIATION. C. Pfeiffer, P. Schoffer, et al. Trans. Amer. Soc. Mech. Engrs.: Pt. A., J. Eng. for Power, vol. 84, no. 1, Jan. 1962, p. 33-8.

The output of silicon cells can be increased above their normal levels by increasing the intensity of radiation incident upon the cells with focusing devices. This paper describes a study of the performance of commercial cells at radiation levels up to 40 times normal solar radiation intensity, and of the problem of temperature control of the cells at these levels. The silicon solar cell is an efficient converter of solar energy to electrical energy. Cells now available can convert up to 14% of normal solar incident radiation into electrical energy. The major drawback of these cells is their high initial cost, which is on the order of $100,000/kw of installed capacity. The cost of a unit area of reflector system can be anticipated to be two orders of magnitude less than that of the corresponding area of silicon cell. The use of focused radiation on cells may have merit in space application where the unit weight of a reflector may be less than that of the corresponding area of cells; in this application, cell temperature control is the critical factor. Experiments have shown that the power output of commercial silicon cells can be increased by at least an order of magnitude over output at normal radiation levels, by increasing the radiation level to the range of 50

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langleys/min. Cell conversion efficiencies drop from 6-8% to approximately 2%. Other cells, designed for operations at higher fluxes, may perform better. Cooling was provided by circulating water over the front and back of the cell. The data show the cells to be useful devices for measuring solar radiation fluxes at levels up to at least 50 langleys/min, with light-generated current proportional to incident radiation.

1-1231. RADIATION CHARACTERISTICS IN THE OPTIMIZATION OF SOLAR HEAT-POWER CONVERSION SYSTEMS.
D. K. Edwards. Contributed by the Solar Energy Applications Committee for presentation at the Winter Annual Meeting, New York, 26 Nov. -1 Dec. 1961, of The American Society of Mechanical Engineers. 8p. ASME 61-WA-158.

Solar heat-power conversion systems may prove feasible for auxiliary power supplies in space or in other regions remote from inexpensive fossil fuels. Such systems typically involve the following components: a concentrator, collector, converter, and radiator. The concentrator, which may be omitted in some simple systems, is a mirror or lens which focuses solar irradiation on the collector. Some of the irradiation is absorbed, and a portion of this heat is transferred from the collector to the closed-cycle converter, which may be an engine with a working fluid or a thermoelectric or thermionic converter. The converter produces useful power and rejects waste heat to the radiator which transfers it by radiation, conduction, or convection, to the surroundings. Important parameters in the selection of radiation characteristics for a solar heat engine are: the temperature at which the collector operates, the magnitude of solid angle over which it is irradiated, and the temperature of the radiator, since these quantities fix which $\alpha(\theta, \phi)$ is best for each component. A previous investigation of optimization of solar

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heat-power systems was concerned with maximizing conversion efficiency. Whitaker has pointed out that for a space vehicle power supply it is the power output per unit mass that is of prime concern. In what follows, optimum values of the mirror size, collector size and temperature, and radiator size and temperature, are found for prescribed spectral characteristics of these components using the criterion of minimum cost per unit output power per mission. Knowledge of these optimum values permits surface thermal radiation characteristics to be evaluated for application in solar heat-power systems. The important conclusion from the analysis presented in this paper is that selective radiation characteristics are of little consequence for solar absorbers when concentrators are used. Only for flat plate collectors do conditions favorable for use of selective characteristics exist, for, if it is economical to use a concentrator, optimum design usually leads to high concentrations and high collector temperatures. In the example presented, it is economical to use a concentrator unless its cost per unit area exceeds two to three times that of the collector.

1-1232. RADIATION DAMAGE TO SILICON SOLAR CELLS.
J. A. Baicker and B. W. Faughnan. Summary Report, 1 July 1960-1 July 1961. David Sarnoff Research Center, Princeton, N. J. 31 July 1961. 27p. Contract: NAS5-457. 33 refs. A61-9857.

Silicon photovoltaic cells have come into widespread use for solar energy conversion, and in particular for power supplies in satellites. The electrical properties of these cells are very sensitive to small amounts of nuclear radiation. The discovery of the Van Allen radiation belts necessitated a revision of estimates of cell life. There are two major uncertainties in calculating the lifetime of a typical solar cell power supply. The first and larger is a lack of information on the intensity and energy spectrum of the trapped particles, the second is a lack of information on the behavior of any given solar cell under specified radiation fluxes. The analysis carried out has resulted in a better understanding of the operation of the silicon photovoltaic cell. The response occurs principally in the base of the cell with only a small fraction coming from the surface layer; radiation damage occurs principally in the base of the cell. Proton, electron, and ultraviolet irradiation of both solar cells and a small selection of possible cover materials is described. From measurements of the photovoltaic response (spectral and current-voltage characteristics) and the minority carrier lifetimes as functions of bombardment, a number of the damage parameters were determined.
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The results are presented in terms of the "critical flux" (the flux required for 25% loss in conversion efficiency), and wherever possible the product of defect introduction rate and recombination cross section is also given. For electron irradiation the damage rates vary strongly with bombarding energy: from just above the displacement threshold (at around 200 kev) to 800 kev there is a change of 10^3 - 10^4 in the damage rate. For proton irradiation the damage rates are quite insensitive to bombarding energy from 1 to 20 mev. The effects of bombardment on minority carrier lifetime and diffusion length are described. Analysis of the spectral response before and after irradiation indicates 1) that most of the photovoltaic response occurs in the base region of the cells, and 2) that virtually all of the damage occurs to the base response. There is a significant difference in damage rates of p on n compared with n on p cells, the p on n being consistently more damage susceptible. The difference drops from a factor of over 1000 at electron bombarding energies near 200 kev to a factor of 2-3 at proton energies of 19 mev. For an uncovered cell, the lifetime would range from 9 days to 1.3 years in the electron belt, and less than 35 hrs in the proton belt. Uncovered p on n cells were sooner damaged than n on p cells. The addition of an 0.030 sapphire cover increases the lifetime of the cell to 2100 hours in the proton belt and to a very large unspecified life in the electron belt. No effect of

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ultraviolet irradiation on the solar cells was found. Except for sapphire and quartz, the cover materials discolored severely under ultraviolet irradiation.

I-1233. RESEARCH STUDY OF PHOTOVOLTAIC SOLAR CELL PARAMETERS. W. Shockley and H. J. Queisser. Shockley Transistor Unit of Clevite Transistor, Mountain View, Calif. Research and Development Lab, ASD TR 61-423. Oct. 1961. 47 p. Contract: AF 33(616)-6707, Proj. no. 3145, Task no. 38231. A62-1180.

This report covers a theoretical study of efficiency limitations for p-n junction solar cells. In order to find an upper limit for efficiency of a solar energy converter, a limiting efficiency, called the detailed balance limit, has been calculated for an ideal case in which the only recombination mechanism of electron-hole pairs is radiative as required by the principle of detailed balance. Efficiency is calculated for the case in which radiative recombination is only a fixed fraction, f_c, of the total recombination, the rest being non-radiative. Efficiency at matched loads have been calculated with band gap and f_c as parameters. Maximum efficiency is found to be 32% for an energy gap of 1.1 ev and F_c=1. Actual junctions do not obey the predicted current voltage relationship, and reasons for the difference and its relevance to efficiency are discussed.

I-1234. TEMPERATURE RISE IN A BARRIER-LAYER PHOTOCELL EXPOSED TO SUNLIGHT. D. Paix. J. Sci. Instruments, vol. 38, no. 12, Dec. 1961, p. 515.

The maximum temperature attained by a solar cell exposed to summer temperatures on a roof is reported to be 136° F. This is very near the permissible limit of heating, and there is no assurance that overheating will not occur on a hot, still, day.

SECTION G - THERMIONIC DEVICES

1-1235. **SOLAR THERMIONIC ELECTRICAL POWER SYSTEM.** General Electric Co., Missile and Space Vehicle Dept., Philadelphia, ASD TN 61-121. Dec. 1961. 33p. illus. Contract: AF 33(616)-7008, Proj. no. 3145, Task no. 60962-6. A62-1182.

Working drawings and fabrication details for a solar thermionic power plant are presented. The generator consists of a deployable solar collector and a thermionic generator so mounted that the solar energy is focused on 105 thermionic diodes that convert the energy directly to power.

SECTION H - THERMOELECTRIC MATERIALS

I-1236. POWER GENERATION AND HEAT PUMPING BY THERMOELECTRIC PHENOMENA. Herbert Mette. Solid State Journal, vol. 2, no. 5, May 1961, p. 23-30.

This paper presents an historical development of thermoelectric phenomena giving a short description and physical background of Seebeck's discovery, Peltier heat pumping, Seebeck effect, Thomson effect and two Kelvin relations. The first of these relations links the thermoelectric power to the Peltier coefficient directly, while the second relation links the derivative of the Seebeck coefficient of the junction between two materials to the Thomson coefficient in each of the junction materials. Further, the absolute thermoelectric power of various solids (metals and semiconductors) is discussed and the values in μV/deg are compiled in a table. Criteria for building power generators is considered from the point of view of the requirements a material must meet in order to qualify for use in efficient thermoelectric devices. It is seen, from equations derived for this purpose, that the efficiency of power conversion depends on two factors: the material constant Z, and the "Carnot efficiency" $\Delta T/T$. In a similar way, the efficiency of Peltier heat pumping and refrigeration also depends on Z and ΔT. Finally, general considerations for design of thermoelectric converters and coolers as well as the application of thermoelectric devices are presented.

II. MATERIALS

SECTION A - GENERAL

I-1237. EIGHTH MATERIALS REVIEW. Arthur Lyem. Army Chemical Research and Development Labs., Army Chemical Center, Maryland, CRDL Special Publication 4-22. Sept. 1960. 80p. AD 246 153. A61-1842.

The purpose of this periodic review is to present important technical and scientific highlights regarding materials research here and abroad, principally in the polymer and plastics fields. The information is intended to serve as a timely and convenient reference for Chemical Corps laboratories and agencies and particularly for development personnel seeking information about engineering materials of actual or potential interest for the creation of more efficient or economical end items. This review briefly discusses a host of materials falling within the following categories: high polymers, plastic materials, synthetic fibers, metals and inorganic materials, and, finally, miscellaneous materials (including new concepts). The physical and chemical characteristics, manufacturing techniques, nuclear aspects (radiological and thermal), medical and biological considerations, and industrial and military applications of these materials are discussed. A literature survey of 264 references is also included.

I-1238. MATERIALS SYMPOSIUM. 13-15 Sept. 1961, Phoenix, Arizona. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., ASD TR 61-322. July 1961. 905p. illus. A61-11375.

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The Future of Analytical Chemistry, by L. Harrah.
Molecular Weight Measurement, by Mary T. Ryan.
Microwave Ferrites, by J. B. Brauer and No. O. Korolkoff.
Hard Magnetic Materials, by K. Strnat.
Soft Magnetic Metallic Materials, by J. C. Olson.

Electronic Material Requirements, by F. E. Wenger.
Dielectric Materials for Advanced Astronautic Weapon Systems, by W. G. D. Frederick and J. I. Wittebort.
Some Aspects of New Polymers for Dielectrics, by G. F. L. Ehlers.
Progress on the Research of Solid State Phenomena and Materials, by W. Metscher.
Refractory Metals as Engineering Materials, by T. D. Cooper.
Aerospace Working Fluids, by D. A. Kirk.
Aerospace Lubricants, by H. W. Adams.
Advanced Lubrication Techniques, by G. A. Beane.
Elastomers, by W. E. Gibbs, W. R. Griffin, and R. G. Spain.
Thermal Emittance Measurements, by R. A. Winn.
Environmental Considerations for Thermal Protective Coatings, by R. M. VanVliet and J. J. Mattice.

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Coatings for Temperature Control in Space Vehicles, by J. H. Weaver and C. Jacobs.
Thermal Protection, by H. Marcus.
Refractory Emissive Coatings, by L. N. Hjelm.
The Effect of Radiation on Solid State Materials and Devices, by B. Manning.
Radiation Chemistry, by R. E. Rondeau and J. Radell.
Radiation Effects on Materials in Space, by R. L. Hickmott, G. H. Griffith, O. L. Donlon, O. V. P. Sessoms, and T. W. Bailey.
Transparent Materials, by R. Wittman.
Unique Metallic Materials and Techniques, by E. M. Kennedy and S. A. Worcester.
Materials Problems in Dynamic Energy Conversion Systems, by G. E. Thompson.
Types of Thermionic Power Converters and Current Materials Limitation, by E. F. Redden.
Solar Cells in Space, by R. W. Runnels.
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Flight Vehicle Power, by D. Mortel.

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Improving the Mutual Guidance and Support Between the Fields of Materials and Design, by W. R. Micks.
Welding and Brazing Space Age Materials, by R. Bowman.
Ceramics and Intermetallics, by I. D. Latva.
Organic and Inorganic Fibrous Materials, by J. H. Ross.
Applied Research Program for Nondestructive Methods Development, by R. R. Rowand.
The Nondestructive Measurements of Surface Connected Discontinuities, by W. L. Shelton.
Ablative Materials, by D. L. Schmidt.
Extrusion of High Temperature Materials, by P. S. Duletsky.
Theoretical Formability, by J. Bryars.
The Mechanical Behavior of Materials, by R. T. Ault, I. K. Ebcioglu, et al.
Beryllium Research and Development, by S. S. Christopher.
Materials for Molecular Electronics, by Elizabeth H. Tarrants.

SECTION B - BERYLLIUM AND BERYLLIUM ALLOYS

1-1239. **PROCESS EXTRUDES SMOOTH BERYLLIUM.** Missiles and Rockets, vol. 10, no. 2, Jan. 8, 1962, p. 24.

The article describes beryllium extrusions fabricated by Northrup Corporation with the technical assistance of Nuclear Metals, Inc. The difficulties encountered in the process are described. Success appears to depend upon the use of metallic lubricants. Mechanical properties (yield strength, ultimate strength, and elongation of specimens of a test extrusion) are given. The extrusions are U-shaped and up to 39 feet in length.

SECTION C - METALS AND ALLOYS

1-1240. **THE EFFECT OF CADMIUM PLATING ON AIRCRAFT STEELS UNDER STRESS CONCENTRATION AT ELEVATED TEMPERATURES.** E. M. Kennedy. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., WADD TR 60-486. Sept. 1961. 73p. illus. Proj. no. 7351, Task no. 73519. A62-1058.

A study has been conducted of the effects of cadmium plating on stressed steels at elevated temperatures. The experimental procedures involved several tests characterized as the stress-rupture tests, tensile tests, and fatigue tests. Several aircraft quality SAE steels (4340, 4130, 1095, 18-8) and H-13 hot work die steels were studied. Strength levels from 180,000 psi to 300,000 psi suitable for the several steels, were evaluated for a variety of conditions of stress concentration. The steels examined, except the austenitic stainless steels were susceptible to embrittlement by cadmium plating at elevated temperatures. With decreasing temperatures, the noticeable effect of cadmium plating on the properties of steels is correspondingly decreased. All the steels examined showing an effect on one property, showed similar effects on the other properties.

1-1241. **EFFECT OF COMBINED STRESS ON YIELD AND FRACTURE BEHAVIOR OF ZIRCALOY-2.** R. L. Mehan. Trans. Amer. Soc. Mech. Engrs.: Pt. D. J. Basic Eng., vol. 83, no. 4, Dec. 1961, p. 499-512.

This investigation was undertaken to understand better the yield and fracture characteristics of Zircaloy-2 as a function of stress state. Zircaloy-2 is a zirconium-tin alloy widely used in reactor cores as fuel elements and as other structural parts. It is known to be highly anisotropic. Because of the importance of these components, and the necessity that they perform satisfactorily without failure, it was considered desirable to ascertain how Zircaloy-2 behaves under combined stress. The yielding and fracture characteristics of Zircaloy-2 as a function of stress state were investigated at room temperature through the medium of thin-walled cylindrical specimens under internal pressure and axial tension. Stress states from uniaxial longitudinal tension to uniaxial tangential tension were examined. Two tests at elevated temperature were performed at a single stress ratio. It was found that the fracture ductility lessened with increasing biaxiality. A minimum in ductility was found at balanced biaxial tension where the fracture ductility, as expressed by the effective strain, was 29%. The yielding and plastic flow properties were found to be highly anisotropic. Two methods were used to express the plastic flow data: a graphical approach and a theoretical analysis

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based on a theory proposed by R. Hill. Either one is suitable to express the flow properties of Zircaloy-2 under various states of combined stress.

1-1242. **EFFECT OF STRESS ON THE CREEP RATE OF HIGH PURITY ALUMINUM IN THE CROSS-SLIP REGION.** N. Jaffe and J. E. Dorn. California. Univ., Berkeley, WADD TR 61-200. Sept. 1961. 20p. Contract: AF 33(616)-7213, Proj. no. 7021, Task no. 73653. 9 refs. A62-383.

The effect of stress on the creep rate of high purity polycrystalline aluminum in the intermediate temperature range was investigated by conducting creep tests at a series of different stresses and by decreasing the stress abruptly during the course of primary and secondary creep. Three series of decreases in stress tests were conducted: the stress was decreased in primary and secondary regions of creep at 347.5°K and the stress was decreased in primary creep at 327°K. The results demonstrate the effects of structure and temperature on the stress dependence of the creep rate. The trends in the creep rate after drop in stress are complicated and show that recovery takes place. The experimental results were compared with Friedel's theory for cross-slip, the experimentally determined energy for a constriction being in good agreement with the theoretical estimate proposed by Stroh.

1-1243. **EFFECTS OF MODERATELY HIGH STRAIN RATES ON THE TENSILE PROPERTIES OF METALS.** D. P. Moon and J. E. Campbell. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC memo 142. 18 Dec. 1961. 33p. 75 refs. A62-1205.

Since the release of DMIC Memorandum 4 on "Effects of High Strain Rates and Rapid Heating on the Tensile Properties of Titanium Alloys," a number of inquiries have been received by DMIC on the effects of high strain rates on other metals and alloys. Because of the general interest, this memorandum has been prepared to show typical effects of increasing the strain rate to nearly 100 in./in./min at room and elevated temperatures on the tensile properties of a number of commercial alloys. In this report the results of tensile tests are discussed and the effects of increased strain rates are plotted for the following materials: aluminum alloys, beryllium, low alloy steel, hot-work die steels, stainless steels (austenistic and heat-treatable), superalloys, and titanium alloys. A bibliography of 75 references is given.

1-1244. **EFFECTS OF SPECIMEN SIZE AND NOTCH ACUITY ON THE BRITTLE FRACTURE STRENGTH OF A HEAT-TREATED STEEL.** S. Yukawa and J. G. McMullin. Trans. Amer. Soc. Mech. Engrs.: Pt. D. J. Basic Eng., vol. 83, no. 4, Dec. 1961, p. 541-44.

One purpose of notched specimen fracture testing is to obtain some indication of the strength of a structural component in the presence of cracks or crack-like defects. For this purpose, information on the comparative effects of a sharp machined notch and a crack is desirable since machined notch specimens are more easily prepared. Effects of various methods of notch preparation of heat-treated alloy steel specimens were studied. Test results indicate that arrested cleavage cracks and short fatigue cracks lower the brittle fracture strength by about 35% compared to a machined notch with approximately 0.005 in. radius. The difference is observed when the specimen size is sufficiently large; with decreasing size, the difference becomes less and may disappear altogether if relatively small specimens are tested. By nitriding the notch, it appears possible to obtain effects with machined radius notches equivalent to cracks.

1-1245. FATIGUE STRENGTHS OF AIRCRAFT MATERIALS. AXIAL-LOAD FATIGUE TESTS ON EDGE-NOTCHED SHEET SPECIMENS OF 2024-T3 and 7075-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL WITH NOTCH RADII OF 0.004 AND 0.070 INCH. H. J. Grover, W. S. Hyler, and L. R. Jackson, Battelle Memorial Inst. National Aeronautics and Space Administration, Washington, D. C., NASA TN D-111. Sept. 1959. 25p. A61-11675.

The present report gives results of axial-load fatigue tests on notched specimens of three sheet materials: 2024-T3 and 7075-T6 aluminum alloys and normalized SAE 4130 steel. Two edge-notched specimens were designed and tested, each having a theoretical stress-concentration factor $K_t = 4.0$. The radii of the notches were 0.004 and 0.070 in. Tests of these specimens were run at two levels of nominal mean stress: 0 and 20,000 psi. For a constant value of theoretical stress-concentration factor $K_t = 4.0$, the fatigue notch factor K_f generally increases as the root radius increases. These fatigue notch factors for specimens with edge notches with $K_t = 4.0$ are in reasonable agreement with K_n values for notches with zero flank angle computed from

$$K_n = 1 + \frac{K_t - 1}{1 + \sqrt{\frac{A}{r}}}$$

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where r is the notch radius and the parameter A = 0.02 in. for the two aluminum alloys and 0.0027 in. for normalized SAE 4130 steel. In considering all data assembled during the broad program on specimens having edge-type notches with various values of K_t and root radius, the Neuber factor K_n was shown to be helpful in predicting the trend of the data using the above values of A. There was evidence, however, that at high values of K_t the predictions would be unconservative, whereas, at low values of K_t, the predictions would be conservative.

1-1246. INELASTIC DESIGN OF LOAD CARRYING MEMBERS. PART IV. THE BEHAVIOR OF BEAM-COLUMNS IN THE INELASTIC RANGE. B. B. Muvdi and O. M. Sidebottom. Illinois. Univ., Urbana, WADD TR 60-580, Pt. IV. July 1961. 60p. Contract: AF 33(616)-7600, Proj. no. 7351, Task no. 73521. 22 refs. A61-8724, pt. 4.

Two theories were presented for constructing either moment-load or load-deflection relations as well as the collapse loads for beam-columns. In each case, trial and error solutions were required which used constant depth of yielding interaction curves. A "so-called" exact theory was presented which gave results as accurate as desired; however, the theory was not practical because of the excessive time required. An approximate theory was presented which gave results in close agreement with the exact theory and with experimental data. This theory required the elastic solution for maximum elastic conditions. The experimental part of the investigation included tests of rectangular- and T-section columns made of 2024-T4 aluminum alloy, SAE 1020 steel, and 17-7PH stainless steel. Several slenderness ratios were considered. In addition to the variable axial load, the columns were subjected to a constant transverse load either at midspan or at quarter span which produced a bending stress of 0.25, 0.50, or 0.75 σ_e.

1-1247. INTRODUCTION TO METALS FOR ELEVATED-TEMPERATURE USE. J. E. Campbell, H. B. Goodwin, et al. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC rept. 160. 27 Oct. 1961. 92p. illus. Contract: AF 33(616)-7747. A62-118.

Modern technology, both military and industrial, is increasingly confronted with temperature limitations. There is a never-ending search for materials capable of performing desired functions at both higher and lower temperatures. This report deals with metals for service at elevated temperatures. Although the technology is relatively well advanced and the metallurgist has a wide background of data on which to base his further developments, there are many people involved in the evaluation of systems and the design and fabrication of structures who have not had an opportunity to obtain this background. This report, therefore, has been prepared primarily for the non-specialist in response to requests for a general review of the field of high-temperature metals in terms understandable to those who have not had extensive metallurgical training. The general categories of metals suitable for application at temperatures in excess of 800° F are discussed, along with the general advantages and limitations of each. Some generalized mechanical-and physical- property data are included, and the problems of reactions at elevated temperatures are briefly discussed.

1-1248. INVESTIGATION OF CREEP BUCKLING OF COLUMNS AND PLATES. PART IV. COLUMN CREEP BUCKLING THEORY AND CORRELATION WITH EXPERIMENTS. George Gerard and Ralph Papirno. New York Univ., New York, WADC TR 59-416, Pt. IV. July 1961. 33p. Contract: AF 33(616)-5807, Proj. no. 7381, Task no. 73812. A61-10555, pt. 4.

A creep buckling theory is developed based upon fundamental concepts of a mechanical equation of state representing the time dependent behavior at instability of column, and also a time dependent formulation of the governing differential equation and stability criterion. The predictions of this theory as well as those of other classical stability hypotheses are then correlated with recent experimental data of creep buckling of 2024-0 aluminum alloy columns. A simplified approach for prediction of creep buckling is also presented and this is correlated with test data on columns of various aluminum alloys, titanium alloys, and 17-7PH stainless steel. Conclusions are drawn as to the predictive value of calssical stability approaches and as to certain important difficulties in correlating the data related to the short time failure behavior of columns at elevated temperatures which seem to have been overlooked in the past.

1-1249. MECHANICAL PROPERTIES OF SOLUTION-TREATED TITANIUM SHEET ALLOY B120VCA. R. G. Henning. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., ASD TR 61-337. Sept. 1961. 154p. illus. Proj. no. 7351; Task no. 73521. A62-396.

Mechanical properties of three heats of solution-treated titanium sheet alloy B120VCA were obtained. These properties included tensile, compressive, sheet single shear, bearing and 105° bend at temperatures of 200°, 400°, 600°, 800°, and 1000° F. Stressed and non-stressed exposure tests were conducted at 600°, 800°, and 1000° F. All properties were determined in both the transverse and longitudinal rolling directions. Curves are presented for mechanical properties vs. test temperature and for the ratio of room temperature tensile properties to compressive, bearing and shear properties vs. temperature. Typical stress-strain curves for tensile and compression tests were drawn for all test temperatures.

I-1250. PROPERTIES OF YTTRIUM AND THE RARE EARTH METALS OXYGEN AND ALLOY SYSTEMS. Bernard Love. Research Chemicals, Inc., Burbank, Calif. Div. of Nuclear Corp. of America, WADD TR 61-123. Aug. 1961. 179p. Contract: AF 33(616)-6829, Proj. no. 7351, Task no. 73517. 49 refs. A61-11691.

The rare-earth rich end of the yttrium, erbium, neodymium, and samarium systems with oxygen were investigated. The solubility of oxygen is low in the metals at temperatures up to the transformation temperature or 1000° C. The transformation temperature of neodymium is essentially unaffected, that of samarium is raised slightly. The nature of the elevated temperature portion of each system is less certain and two alternative phase diagrams are proposed. The preferred diagram indicates the presence of a high temperature interstitial monoxide. The cobalt end of the cobalt-erbium system was investigated. A number of intermetallic compounds are formed. The first of these, $Co_{17}ER_2$, enters into eutectic reaction with cobalt. The solubility of erbium in cobalt is low, and the cobalt phase transformation is essentially unaffected by the presence of small additions of erbium. The cobalt-yttrium system appears to be similar. Tantalum-lanthanum, tantalum-erbium, tantalum-yttrium, niobium-erbium, and niobium-yttrium systems were investigated. All systems were similar in their general characteristics.

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The alpha to beta transformation temperature was determined to be 848° C for neodymium, and 930° C for samarium. The transformation temperature of yttrium is approximately 20-30° C below the melting point of yttrium. Both the transformation and melting temperatures are somewhat dependent upon metal purity. Atmospheric corrosion rates were determined in the above systems. Lower rates were found for certain niobium alloys, and for cobalt compositions, with added rare earths. Improved mechanical properties were found for yttrium-erbium alloys and for yttrium-zirconium alloys ascribed to solid solution hardening. The latter age at room temperature, and rapidly overage at elevated temperatures. Procedures for purification of yttrium and erbium by vacuum distillation were developed. Improved methods for oxygen and tantalum analysis are described. The addition of erbium to beryllium yields alloys indicating improved purity and grain refinement.

1-1251. RESEARCH AND DEVELOPMENT ON HIGH-PRESSURE-HIGH-TEMPERATURE METALLURGY. L. Kaufman, S. V. Radcliffe, et al. Manufacturing Labs., Inc., Cambridge, Mass. Research Div., WADD TR 60-893. Aug. 1961. 156p. illus. Contract: AF 33(616)-6837, Proj. no. 7351, Task no. 73517. 78 refs. A61-11643.

The accomplishments of the contract period 8 Oct. 1959-7 Feb. 1961 are summarized. The experimental investigations on the effect of high hydrostatic pressure on phase transformations in various substitutional iron-base alloys, including iron-chromium, iron-nickel and iron-silicon, yield data which are in close agreement with theoretical prediction. A study of the effects of pressure on iron-carbon alloys shows a general shift of the equilibrium phase boundaries to lower carbon contents and temperatures with pressure. Pressure also acts to retard both the rate of tempering and the isothermal transformation of metastable austenite. The synthesis of fcc MoC has been carried out at pressures in excess of 35 kilobars at a temperature of 2000° C. The thermally activated recovery and recrystallization processes are shown to be retarded in a study of copper and 70-30 brass. Experimental data have been obtained for the effect of pressure on the Hall voltage of cerium. Preliminary studies have been carried out on the high pressure sintering of Al_2O_3.

1-1252 SHORT-TIME TENSILE PROPERTIES OF TYPE 316 STAINLESS STEEL AT VERY HIGH TEMPERATURES. T. W. Gibbs and H. W. Wyatt. Trans. Amer. Soc. Mech. Engrs.: Pt. D. J. Basic Eng., vol. 83, no. 4, Dec. 1961, p. 481-8.

Superalloys and refractory metals are usually considered for severe high-temperature service. The disadvantages include high cost, lack of availability, and the difficulty of fabrication. Also, many of the superalloys suffer drastic loss of strength beyond their intended temperature range of application because of deteriorating solid-state reactions such as overaging and corrosion. The unique short time-temperature histories in missile design allow for the consideration of materials originally not intended for very high-temperature service. An evaluation program was conducted on Type 316 stainless-steel sheet material to determine the effects of residual cold-work and welding on the room-temperature and elevated-temperature mechanical properties to 1800° F. Short-time tensile and tensile-creep elongations tests were run to determine the stresses required to produce elongations up to 10% in 2 min. Welds in tension lowered the elongation with no loss in strength. Cold-work on the annealed material increased the strength properties appreciably, thus allowing for higher design stresses.

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The results of a few tests indicate that Type 316 stainless steel retains some strength properties up to 2300°F. A definite stress-strain relationship exists in which the 0.2% yield stress is very close to the tensile stress. For short times, on the order of 2 min, at high temperatures, stresses approaching the tensile strength can be sustained with less than 10% elongation. Short time heating data clearly indicate that the 2-min creep curves would apply also to heating time of 30 to 1800 seconds.

1-1253. STANDARD DESIGNATIONS OF ALLOYS FOR AIRCRAFT AND MISSILES. TRADE NAMES, AERONAUTICAL AND MILITARY SPECIFICATIONS, AND PRODUCERS OF STAINLESS STEELS, ALLOY STEELS, AND SUPERALLOYS. J. J. Vagi and A. F. Haskins. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 42R. 24 May 1961. 78p. A61-5493.

Four tabulations are included in this memorandum:

TABLE 1--TRADE DESIGNATIONS. This table is a numerical and alphabetical listing of metals and alloys by trade designations and is the major table in this compilation. TABLE 2--AERONAUTICAL MATERIAL SPECIFICATIONS (AMS). An effort was made to include AISI, SAE, and trade designations in this tabulation of Aeronautical Material Specifications. To determine the nominal chemical composition, reference should be made to the trade designations in Table 1. TABLE 3--HOT-WORK TOOL STEELS. AISI designations are given in Table 3 for the hot-work tool steels (Symbol H). Chemical compositions corresponding to the AISI designations may be found by reference to the trade designations in Table 1.

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TABLE 4--SELECTED HIGH-STRENGTH AND HEAT- AND CORROSION-RESISTANT ALLOYS. Selected high-strength and heat- and corrosion-resistant alloys are listed in this table by AISI designation. Chemical compositions corresponding to the AISI designations are given in the numerical listing of Table 1.

1-1254. STRESS REDISTRIBUTION IN NOTCHED SPECIMENS UNDER CYCLIC STRESS. A. B. Blatherwick and Byron K. Olson. Minnesota. Univ., Minneapolis, ASD TR 61-451. Oct. 1961. 26p. Contract: AF 33(616)-6828, Proj. no. 7351, Task no. 73521. A62-1057.

Most materials exhibit a change in stress-strain relationship when subject to fatigue stresses. In this work, the effect of this change on the stress distribution across the throat of notched plate specimens of mild steel is examined. Using a series of strain gages, the strain distribution across the specimens was determined under dynamic conditions for various numbers of cycles. Tests of unnotched specimens were used to obtain the cyclic stress-strain properties for corresponding numbers of cycles, and from these data the stress distribution in the notched specimens was determined. Good agreement was obtained between the integral of the stress distribution curve and the total load on the specimen. Tests in which the strain amplitude at the notch root was held constant revealed a decreasing maximum stress with fatigue cycles. In another series of tests, in which the load amplitude was constant, the maximum stress amplitude was observed to decrease with number of fatigue cycles despite an increasing strain amplitude. In both

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types of test, the stress concentration factor was observed to decrease with increasing average-stress amplitude, a further decrease occurring with an increasing number of fatigue cycles.

1-1255. SUPERIOR ALUMINUM AND MAGNESIUM CASTINGS BY CENTRIFUGAL CASTING AND PERMANENT MOLDING. A. J. Iler. Final Technical Engineering Report, Mar. 1959-June 1961. Northrop Corp. Norair Div., Hawthorne, Calif., ASD TR 61-7-215k. Oct. 1961. 102p. illus. Contract: AF 33(600)-38450, Proj. no. 7-215k. A62-386.

Considerable interest has been focused on high tensile properties produced in light alloy castings made by the permanent mold centrifuge method. Some of the reasons why this process should produce higher properties than is normally attained by other processes are developed in this report. Interest has also been evidenced in various efforts to elevate mechanical properties of aluminum and magnesium permanent mold castings by variations of mold materials and processes. It was the purpose of work under Air Force contract AF 33(600)-38450 to exploit these and other materials and techniques in order to develop improved methods for consistently producing quality, high strength, lighter weight aluminum and magnesium castings using permanent mold and centrifugal force techniques. The chief value of data given in this report lie in the added criteria for a much expanded use of centrifugal permanent mold castings for critical structural uses in military airframe design, and for definition of a solidification pattern for which new aluminum and magnesium base alloys can be developed.

1-1256. A SURVEY OF THE LITERATURE ON THE USE OF ORGANO-METALLIC COMPOUNDS IN THE PREPARATION OF ULTRA-PURE METALS. W. A. G. Graham. Little (Arthur D.) Inc., Cambridge, Mass,, ERD-TN-60-768. 15 July 1960. 41p. Contract: AF 19(604)-4975. AD 242 291. 122 refs. A62-682.

A survey of the literature on methods for recovering metals from organo-metallic compounds has been carried out. Possible recovery methods are thermal decomposition, photolysis, electrolysis, and hydrogenolysis. These have been appraised from the standpoint of contamination of the product by organic residues. Reaction of metals with gaseous organic free radicals has also been reviewed, but does not appear attractive as a means of purification. Reactions of organic free radicals in solution with metals are also discussed.

1-1257. THE TECHNOLOGY OF SCANDIUM, YTTRIUM, AND THE RARE EARTH METALS--A LITERATURE SURVEY. Bernard Love. Research Chemicals, Inc., Burbank, Calif., WADD TR 60-864. Apr. 1961. 229p. Contract: AF 33(616)-6829, Proj. no. 7351, Task no. 73517. A61-11498.

A survey has been made of the unclassified literature relating to the rare earth elements. The best available data has been compiled for the abundance and distribution of the elements, the methods of recovery from ores, separation and purification techniques, and procedures for reduction to metal. The physical, chemical, and mechanical properties of the elements and their important compounds are presented in the form of tables and charts. Rare earths, rare earth metals, rare earth metal systems, and metal alloy systems containing rare earths are considered in this report. The bibliography contains 939 references.

1-1258. **TENSILE PROPERTIES OF AISI TYPES 304 AND 347 STAINLESS STEELS AT MODERATE TEMPERATURES FOR SECTION SIZES RANGING FROM BARS TO EXTREMELY LARGE FORGINGS.** W. H. Pryle and E. T. Wessel. Trans. Amer. Soc. Mech. Engrs.: Pt. D. J. Basic Eng., vol. 83, no. 4, Dec. 1961, p. 489-98.

New applications have been found for austenitic stainless steels, particularly in the nuclear-reactor field. Precise data on mechanical properties, particularly yield strength, are necessary. Consideration must be given also to the possibility of localized yielding because of high thermally induced stresses. It is important, therefore, to know what sort of variations of properties can be expected in different lots of a given type of steel and in different section sizes. Few data have been available for the temperature range from room temperature to 800°F. The tensile properties of AISI types 304 and 347 annealed stainless steel were investigated for the temperature range from 75° to 800°F. Several lots of materials were studied in each of several section sizes ranging from bar stock to extremely large forgings. A considerable variation in properties, particularly yield strength and elongation, were observed between different lots of a given type of steel of a given size category. These variations correlated with variations in the annealed hardness and are attributed to the use of different (cont.)

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annealing treatments by the suppliers. At equivalent hardness levels the properties obtained from the various section sizes were comparable. Within any given lot or forging, the properties were quite uniform for equivalent specimen orientations. The transverse ductility of the large forgings was considerably less than the longitudinal ductility. However, this relatively poor ductility did not lead to notch sensitivity or embrittlement problems.

1-1259. **A TENSILE TESTING APPARATUS FOR SHORT FINE FILAMENTS WITH OPTICAL-MECHANICAL STRAIN MEASUREMENT.** J. E. Emrick and H. L. Gegel. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., ASD TR 61-168. Sept. 1961. 13p. illus. Proj. no. 7021, Task no. 73653. A62-1053.

An apparatus was designed and built which will obtain relatively accurate stress-strain curves of fine metallic filaments and whiskers. The principle of operation is based upon the extension of a calibrated spring to apply the load. The strain is measured optically by projecting the gauge marks on two ground-glass plates attached to dial indicators. The magnitude of error in load and strain measurements is very slight. Stress-strain measurements of elastic moduli for two filament metals were made as a final check.

SECTION D - REFRACTORY MATERIALS

1-1260. DEVELOPMENT OF HIGH STRENGTH MATERIALS FOR SOLID ROCKET MOTORS. PROGRESS REPORT, FABRICATION OF PYROLYTIC GRAPHITE SOLID ROCKET NOZZLE COMPONENTS. General Electric Co., Cincinnati. Flight Propulsion Lab. Dept. 8 Oct. 1960. 3p. illus. BuWeps Contract: NOrd 18119, Tasks no. 5 and 6. A61-10850.

This memorandum contains reports on the revised objectives in the work of fabricating full-scale hardware (coated ATJ graphite first, second, and third stage throat inserts) for evaluation testing at the facilities of Aerojet General Corporation and Allegany Ballistic Laboratory, and also on the work accomplished under Tasks no. 5 and 6 of this program. Two A2 throat inserts fabricated under Task no. 5 are analyzed with respect to defects (circumferential and axial cracks) and the quality of the pyrolytic graphite itself. Further, three Allegany Ballistic Laboratories test nozzles fabricated under Task no. 6 are discussed. These nozzles have a throat diameter in excess of 0.990 in. (0.020 in.-0.040 in. oversize). The fabrication of a smaller throat diameter version of this test nozzle (0.710 in.) was started.

1-1261. DEVELOPMENT OF NIOBIUM-BASE ALLOYS. Richard T. Begley and William N. Platte. Westinghouse Electric Corp. Aviation Gas Turbine Div., Kansas City, Mo., WADC TR 57-344, Pt. IV. May 1960. 122p. illus. Contract: AF 33(616)-5754, Proj. no. 7351. AD 240 980. 26 refs. A61-9879, Pt. 4.

Vacuum tensile data were obtained for pure niobium from room temperature to 1371°C (2500°F). The data for niobium followed the general pattern exhibited by other pure refractory metals. The ductile-brittle transition (in impact) for commercial-purity, arc-melted niobium was close to room temperature. The effect of binary additions of Ti, Zr, Hf, V, Mo, W, Re, Al, and Y on the hardness and workability of niobium was determined. Nb-Ti and Nb-Y alloys had excellent cold workability. Mechanical property data were obtained at room temperature and 1093°C (2000°F) on niobium containing additions of Ti, Zr, Hf, V, Mo, and W. Of the elements studied, vanadium additions were the most effective strengtheners. Nb-Zr and Nb-Hf alloys having high oxygen contents had very good high temperature properties. It appears that the interaction of oxygen with the alloy addition may be responsible for the high strength. Tensile data were also obtained on alloys

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having ternary and quaternary additions of Ti, Zr, Hf, and Mo. Nb-Ti-Zr-Hf alloys exhibited yield strengths well in excess of 40,000 psi at 1093° C (2000° F). Welding studies on a number of niobium alloys containing additions of Ti, Zr, Hf, V, and W were carried out. Satisfactory welds were obtained in all the alloys studied. Bend test data were obtained on the weld specimens.

1-1262. DEVELOPMENT OF NIOBIUM-BASE ALLOYS. Richard T. Begley, William N. Platte, et al. Westinghouse Electric Corp. Research Labs., Pittsburgh, WADC TR 57-344, Pt. V. Sept. 1961. 134p. Contract: AF 33(616)-6258, Proj. no. 7351; Task no. 73512. 32 refs. A61-9879, pt. 5.

The effect of oxygen and nitrogen additions on the hardness, workability, strain-hardening characteristics, and recrystallization behavior of niobium was determined. Nitrogen additions were found to be detrimental to cold rolling characteristics. Hardness, workability, and mechanical property data for Nb-C alloys were obtained. Grain boundary carbides were found to be very detrimental to cold workability. Carbon additions increased the ductile-brittle transition temperature range of niobium. Mechanical property data were obtained for many binary, ternary and quaternary niobium base alloys. Re, W, and Mo additions increased the ductile brittle transition of niobium. A number of alloys were prepared by the consumable electrode arc melting process. Ingot breakdown was accomplished by high energy rate extrusion (Dynapak). The results of Dynapak extrusion were very encouraging. Several high strength alloys were investigated. One alloy, Nb-10W-5V-1Zr, had excellent room temperature ductility and ultimate tensile strengths of 64,800 psi and 29,450 psi at 1205° C (2200° F) and 1315° C (2400° F) respectively. Welding data for a number of Nb-base alloys are also presented.

1-1263. DEVELOPMENT OF OPTIMUM METHODS FOR THE PRIMARY WORKING OF REFRACTORY METALS. R. W. Tombaugh, R. C. Green, and J. H. Gehrke. Harvey Aluminum, Torrance, Calif., WADD TR 60-418, Pt. II. Aug. 1961. 219p. Contract: AF 33(616)-6377. A61-11642, pt. 2.

The objective of this program was to provide for the research and development of new processes and techniques for the primary working of refractory metal alloys by hot extrusion. The process developed during the first year has been considerably improved and has been used successfully in extruding refractory metals at temperatures above 4000°F. This has required the development of improved high temperature billet lubrication, novel die designs utilizing ceramic facing materials, high temperature heating facilities, and methods for accurately sensing billet temperatures. This work has been performed at the Metallurgical Experimental Plant of the Aeronautical Systems Division and the operating level of the equipment located therein has been raised accordingly. The suitability of the process has been established by metallurgical evaluation of extruded materials which have demonstrated a high degree of amenability to subsequent

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reworking by conventional methods. In addition, the extrusion process as developed has been applied to a wide variety of refractory metal alloys and has been useful in providing a substantial quantity of wrought materials for other contractors and governmental agencies.

1-1264. FABRICATION OF TUNGSTEN FOR SOLID-PROPELLANT ROCKET NOZZLES. R. I. Jaffee, D. J. Maykuth, and V. D. Barth. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC memo 136. 2 Nov. 1961. 27p.. illus. A61-11547.

The purpose of this memorandum is to summarize information on 1) the consolidation and fabrication processes being used to produce large tungsten shapes and sheet, 2) the general physical characteristics of the various types of tungsten being shaped into rocket nozzles, and 3) the performance of these in solid-fuel rocket motors. Arc melting of tungsten has only recently been accomplished, and the arc casters have produced only relatively small ingots. Tungsten castings for utilization as nozzles in the cast condition have chiefly been confined to tungsten-molybdenum alloys. Electron-beam melting is an even newer process. The development of electron-beam furnaces is proceeding quite rapidly; the largest electron-beam tungsten ingot so far melted was 4 inches in diameter. Consolidated tungsten for fabrication has been produced by the plasma spraying process. Successes in the direct forging of tungsten nozzle inserts have largely been restricted to billets prepared by pressing and sintering. So far, forging billets from arc-cast or electron-beam tungsten have not been produced in

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sizes large enough to be forged into nozzle inserts. Recently, the first-known successes with the ring rolling of tungsten were reported by Reisner Forge Company. The major limitations in producing wide sheets are small-size sheet bar and inadequate furnaces for sintering and preheating for rolling. Arc-cast tungsten may prove to be ideally suited for fabricating tungsten sheet. Most of sheet-metal tungsten liners so far evaluated have been produced by conventional spinning, a process which does not reduce thickness. Shear spinning is less advanced than conventional and is a more costly process. Explosive forming is in a more primitive stage and is of interest mainly for asymmetric nozzles. Tungsten can be deep drawn if it is heated, and some work in fabricating full-scale nozzles by this process has been done. The fusion welding of tungsten has been remarkably successful. The major techniques are tungsten inert-gas-shielded (TIG) and electron-beam welding. Brazing is primarily of interest in joining sheet-metal liners to graphite backing. Conventional machining of tungsten is a very difficult, time-consuming operation and efforts are being made to employ electrolytic or electrical-arc discharge processes. Plasma or vapor-deposition processes have not yet made great progress, as far as production applications are concerned. Full-scale firing tests at high

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pressures indicate that the most reliable material available for nozzle inserts is pressed, sintered, and forged tungsten. Sheet tungsten is of major importance for nozzle inserts, jetavators, blast tubes and entrance caps. A host of materials have been evaluated as nozzle-component materials for solid-rocket motors. Two general types of composites containing tungsten have shown a measure of success and are being further developed. One type is tungsten based, to which other materials are added to improve properties such as the thermal-shock, heat-absorbing capacity of composites. The other type consists of refractories to which tungsten is added to supply structural integrity, particularly resistance to thermal shock. It is probable that currently contemplated tungsten-sheet capabilities will be satisfactory for producing sheet-metal liners no matter what diameter of nozzle is required, because of the success of tungsten welding.

1-1265. INVESTIGATION OF INTERMETALLIC COMPOUNDS FOR VERY HIGH TEMPERATURE APPLICATIONS. Jonathan Booker, Robert M. Paine, and A. James Stonehouse. Brush Beryllium Co., Cleveland, WADD TR 60-889. Apr. 1961. 143p. Contract: AF 33(616)-6540, Proj. no. 7350, Task no. 73500. A61-11225.

Intermetallic beryllides from the systems tantalum-beryllium, tungsten-beryllium, and hafnium-beryllium, along with the disilicides of tungsten, tantalum, and molybdenum were screened for compounds capable of serving as structural materials at temperatures above 2500°F. The compounds studied were $TaBe_{12}$, Ta_2Be_{17}, Hf_2Be_{21}, $MoSi_2$, $TaSi_2$, and WSi_2. The preparation, fabrication, oxidation resistance, and thermal-shock resistance are discussed. Values are given for the transverse-rupture strengths, impact resistance, mean-linear coefficients of thermal expansion, enthalpy, specific heat, and thermal conductivity. An investigation of the rates of oxidation of intermetallic beryllides was initiated. The oxidation of $TaBe_{12}$, Hf_2Be_{21}, $ZrBe_{13}$, and Ta_2Be_{17} in the range 2300° to 2750°F was found to obey an exponential rate law which was cubic or a higher power.

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In most cases, the cubic rate law applied. The products of the oxidation of $ZrBe_{13}$ at 2500°F were identified as Zr_2Be_{17} and BeO. Tentative activation energies for a cubic rate process were calculated for $TaBe_{12}$ and Hf_2Be_{21}.

1-1266. **RESEARCH AND DEVELOPMENT ON ADVANCED GRAPHITE MATERIALS. VOLUME I. OBSERVATIONS BY ELECTRON MICROSCOPY OF DISLOCATIONS IN GRAPHITE.**
Richard Sprague. National Carbon Co. Research Labs., Cleveland, WADD TR 61-72, Vol. I. Sept. 1961. 27p.. illus.
Contract: AF 33(616)-6915, Proj. no. 7350, Task no. 73503; Proj. no. 7381, Task no. 73811; Proj. no. 7-817.
A62-385, vol. 1.

The preliminary results of an electron microscope study of graphite single crystals are reported in this paper. Methods of preparation for study are outlined. Electron microscope photographs of several types of graphite dislocations are shown and a brief discussion of the photographs is included.

1-1267. SILICA MICROBUBBLES. J. W. Lefforge. Report from July 1958-Nov. 1959. Emerson & Cuming, Inc., Canton, Mass., WADD TR 60-201, Pt. I. 63p. illus.
Contract: AF 33(616)-5840, Proj. no. 7340, Task no. 73402. A61-11370.

Glass microbubbles 0.150 to 0.020 mm diameter, having a bulk density of 0.25 g/cc and a true density of 0.50 g/cc have been greatly improved by decreasing the alkali content and also by making them of vitreous silica. The improvements consist of marked decrease in moisture absorption, enhanced electrical properties, and great increase in maximum use temperature. An acid leaching technique applied to the commercially available 18% alkali "Eccospheres" of Emerson & Cuming, Inc. reduces the alkali content to 6% and increases the maximum use temperature from 500°C to 800°C. A vitreous silica bubble formed from pure silica by a direct high temperature process retains the useful characteristics of the low-melting-alkali-glass bubble along with the desirable properties of vitreous silica, i.e., low to negligible moisture absorption, outstanding dielectric properties even at high temperature, and a safe use temperature for most applications of 1300°C. The feasibility of the direct process has been briefly demonstrated on a pilot plant scale of 2 lb/hr rate.

SECTION E - PROTECTIVE FINISHES AND COATINGS

1-1269. COATINGS FOR REFRACTORY METALS, FORMED BY ANODIC TREATMENT AND BY VAPOR DEPOSITION. Vernon A. Lamb and John L. Sligh. National Bureau of Standards, Washington, D. C. Metallurgy Div, Electrodeposition Section, WADD TR 61-64. Sept. 1961. 24p. Contract: AF 33(616)-60-2, Proj. no. 7312, Task no. 73120. 28 refs. A62-1203.

Preparation of anodic coatings on niobium, tantalum, molybdenum, and tungsten was investigated. The object was to modify such coatings by anodically incorporating elements known to form oxidation protective alloys with these refractory basis metals, and to convert the mixed coatings to a high-temperature oxidation protective film by subsequent reduction and sintering. Anodizing was carried out in both aqueous solutions and in molten salts. Successful coatings were not obtained. Attempts to form aluminide coatings by diffusion of electrodeposited aluminum, followed by anodizing, were also unsuccessful. Efforts were therefore turned to the preparation of coatings by combining electrodeposition and vapor deposition. Specifically, chromium silicide coatings, formed by vapor phase siliciding of electrodeposited chromium, were investigated. Sound coatings were not obtained from hydrogen reduction of $SiCl_4$ due to chemical displacement reaction with the basis chromium. Siliciding with monomethyl and tetramethyl silane avoided the

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displacement reaction and yielded sound silicon carbide coatings. However, these coatings failed to provide good oxidation protection at 1100° C in air, due to spalling. The differential thermal coefficient of expansion with respect to the basis metal was the probable cause of failure.

1-1269. DEVELOPMENT AND EVALUATION OF HIGH TEMPERATURE PROTECTIVE COATINGS FOR COLUMBIUM ALLOYS. PART II. COATING EVALUATION. R. A. Jefferys and J. D. Gadd. TAPCO, Thompson Ramo Wooldridge Inc., Cleveland. Materials Processing, ASD TR 61-66, Pt. II. Sept. 1961. 103p. Contract: AF 33(616)-7215, Proj. no. 7351, Task no. 73512. A62-1051.

An attempt was made in this evaluation program to obtain a limited amount of truly comparative data on six promising coatings for columbium which were applied to the same three base materials (D-31 alloy, F-48 alloy, and unalloyed columbium) and tested under identical conditions. Eighteen coating-base metal systems were tested in cyclic oxidation tests at 2300 and 2500° F, thermal shock-erosion tests from 2500 to 250° F followed by an exposure in air for 1 hr at 2500° F, bend-ductility tests after exposure in air and in vacuum for 2 and 6 hrs at 2500° F and tensile tests at RT and 1000° F after stress-oxidation exposures at a stress of 20% of the base metal yield strength at 2500° F. Cyclic oxidation tests have shown that columbium base materials can be protected from severe oxidation damage for approximately 200 hrs at 2500° F and 300 hrs at 2300° F in air. Bend-oxidation tests indicate that low-temperature bend-ductility in coated, D-31, F-48 alloys and

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unalloyed columbium can be maintained for at least 6 hrs at 2500° F. In general, the higher the thermal treatment in coating, the higher the brittle-to-ductile transition temperature of D-31 or F-48 alloys, and the less the overall low-temperature ductility of the coating-base metal system. Thermal shock tests indicate that coatings can protect columbium alloys under conditions of severe thermal shock from 2500 to 250° F followed by exposure at 2500° F in air. However, it was shown in the tests that the coatings may be more susceptible to low temperature thermal shock than to cycling from 2500° F, as indicated by the high incidence of cold zone failures.

1-1270. ULTRASONIC METHODS FOR NONDESTRUCTIVE EVALUATION OF CERAMIC COATINGS. W. E. Lawrie. Illinois Inst. of Tech., Chicago. Armour Research Foundation, WADD TR 61-91, Pt. I. Apr. 1961. 42p. illus.
Contract: AF 33(616)-6396, Proj. no. 7360, Task no. 73606. A62-1204, pt. 1.

This report describes investigations into the use of ultrasonics to detect defects in ceramic-metal bonds and to measure the strengths of the bonds. In the techniques investigated, ultrasonic frequencies from 30 cps to 35 mc/s have been used, and in one method two frequencies are used simultaneously. Low frequency energy (14 kc/s) has been successfully used to detect defects by decrement measurements. Low frequencies have also been used in further studies of the intermodulation method used to locate regions of bonds in which defects are present. High frequencies, up to 35 mc/s, have been used with a transmission method and visual images of defects are displayed using a simple charge scanning technique. High frequency energy has also been used in the form of surface waves. This work is a continuation of investigations reported in WADD TR 60-157.

SECTION F - ELECTRIC, ELECTRONIC AND MAGNETIC MATERIALS

1-1271. CONTINUOUS CASTING OF THERMOELECTRIC MATERIALS. Ralph J. Hach, Maurice J. Brau, and T. S. Burkhalter. Rev. Sci. Instruments, vol. 32, no. 12, Dec. 1961, p. 1341-3.

The materials which have received the most attention for thermoelectric cooling are bismuth telluride and solid-solution alloys of this compound with bismuth selenide and antimony telluride. These materials have been prepared by a number of methods. If the process of freezing from the melt is slow, as is the case with many methods, dopant segregation and nonuniformity may become very large. This paper describes an apparatus designed to produce uniform material by rapid freezing from a well-stirred melt. This prevents segregation and nonuniformity. The application of pressure to the melt prevents coring during the rapid freeze. The die is heated near the top and cooled near the bottom; it is equipped with a stirrer in the heated portion. Constant removal of solid material from the bottom of the die by an external draw mechanism permits continuous casting. Bismuth telluride and alloys of bismuth telluride, antimony telluride, and bismuth selenide have been cast in rods up to 70 inches in length. The deviation of thermoelectric properties throughout the length of the rods was less than 5%.

1-1272. EFFICIENCIES OF PHOSPHORS FOR SHORT-WAVE ULTRA-VIOLET EXCITATION. A. Bril and W. Hoekstra. Philips Research Repts., vol. 16, no. 4, Aug. 1961, p. 356-70, 8 refs.

The absolute radiant efficiency and quantum efficiency of phosphors, especially for the standard samples issued by the National Bureau of Standards (Washington), for short-wave ultra-violet excitation, are measured using a fast thermopile with a constant spectral power response as detector. The results of the measurements are given in tables III and IV. A simple method for relative efficiency measurements making use of a standard phosphor (e.g., $MgWO_4$) is described.

1-1273. GROWN P-N JUNCTIONS IN SILICON CARBIDE, II. . . . C.A.A.J. Greebe and W. F. Knippenberg. Philips Research Repts., vol. 16, no. 4, Aug. 1961, p. 389-98.

The distribution of current density over the junction area in grown p-n junctions in SiC is found to be inhomogeneous in many samples. Analysis of the spectral distribution of the p-n liminescence for photon energies greater than the bandgap shows that, after correction for inhomogeneous emission of light, this luminescence tends to fit the van Roosbroeck-Shockley theory. A forward characteristic showing several current components is described and analyzed.

1-1274. PHOTO-ELECTRIC EMISSION FROM CADMIUM TELLURIDE. J. J. Scheer and J. van Laar. Philips Research Repts., vol. 16, no. 4, Aug. 1961, p. 323-8.

The photo-electric emission from single crystals as well as from evaporated layers of CdTe has been measured. The resulting photo current vs photon energy curves all show a tail at the long-wavelength side which is ascribed to impurities. It is concluded that the most reliable value for the work function is obtained from measurements on freshly cleaved single crystals. A possible relationship between the photoemissive properties of CdTe and CdS is discussed.

1-1275. PROPERTIES OF FLAT NICKEL-CHROMIUM FILM RESISTORS.* William E. Isler. Diamond Ordnance Fuze Labs., Washington, D.C., Rept. no. TR-948. 26 June 1961. 21p. illus. Dept. of the Army Project DA-5N06-01-010 OMS-5530.11.56900, DOFL Proj. no. 90291. 14 refs. AD 263 388. A61-11698.

Vacuum-deposited resistors, with values ranging from 35 to 4700 ohms per square were prepared and studied. The resistors were made by first depositing a layer of nickel-chromium on glass substrates and then a protective layer of silicon monoxide. Heating at 250°C for 10 min caused the values of the resistors to increase by 95% for the thinnest films and by 0.3% for the thickest. A shelf-life study of the test resistors showed most of them to be stable within ± 10% over a period of more than 3000 hrs of storage at room temperature; for the same resistors, the change due to storage in air at 70°C for 2900 hrs ranged from 4.5-27%. It was found that reproducible resistors were more readily obtained when the end contacts or electrodes were deposited over the resistor films than when this procedure was reversed. Power capacities up to 1.7 w/cm^2 were measured. Excluding annealing effects, the values of temperature coefficient of resistance varied from +4 to -220 ppm/°C. It is concluded that the resistors are adequate for certain circuit applications; however, with respect to power capacity, certain limitations must be taken into account.

1-1276. A RED ELECTROLUMINESCENT ZnSe PHOSPHOR. W. G. Gelling and J. H. Haanstra. Philips Research Repts., vol. 16, no. 4, Aug. 1961, p. 371-5.

The preparation of an efficient, red electroluminescent phosphor, consisting of zinc selenide activated with copper and aluminum, is described. At higher frequencies (1500 c/s) the quantum output proves to be equal to the quantum output of a standard green ZnS(Cu, Al) electroluminescent phosphor under the same operation conditions.

1-1277. SUPERCONDUCTIVITY IN METALS AND ALLOYS.
W. H. Cherry, G. D. Cody, et al. Radio Corp. of America. RCA Labs. Div., Princeton, N. J., WADD TR 60-919.
June 1961. 53p. & Bibliography. Contract: AF 33(616)-6405, Proj. no. 7371, Task no. 73711. 46 refs. A62-384.

Methods have been developed for the measurement of interphase energy in superconductors. A description of method is given along with the preliminary results of measurements on thin foils and films of tin. A proposed examination of the thermal contact resistance (Kapitza resistance) between metals and liquid helium is described. The apparatus is designed to measure changes in this contact resistance at the superconducting transition as well as in the normal state. Measurements have revealed that both hydrogen and deuterium depress the superconducting transition temperature of lanthanum, hydrogen depressing it more than deuterium. Measurements have been made of the transition temperatures in the system (Nb, Ta, V)$_3$Sn. The transition temperatures range from 2.8°K to 18°K and can be related to a simple mass and volume dependence. Critical field measurements indicate behavior similar to that in other "hard" superconductors. Resistance measurements have revealed a resistance anomaly near 100°K which can be related to an existing theory. It has been found possible to prepare films of Nb_3Sn by a transport reaction. Alloying (cont..)

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experiments indicate ambiguities in the electron-to-atom ratio ascribed to various elements.

SECTION G - PLASTICS AND COMPOSITES

1-1278. ABLATIVE PLASTICS FOR REENTRY THERMAL PROTECTION. D. L. Schmidt. Wright Air Development Center, Wright-Patterson AFB, Ohio, Aeronautical Systems Div., WADD TR 60-862. Aug. 1961. 85p. illus. Proj. no. 7340; Task no. 73400. A61-11758.

The unique behavior of plastic materials in very high temperature environments provides a simple, efficient, and reliable means for thermal shielding of hypersonic reentry vehicles. Extreme temperatures and aerodynamic heating associated with these vehicles are accommodated with ease by a phenomenal heat and mass transfer process known as ablation. The ablation of plastics is a complex energy absorptive and dissipative process in which surface material is degraded and removed. Important physicochemical aspects of this process are reviewed. It is shown that ablative performance depends critically upon certain materials and environmental factors. Materials variables of importance include: a) type of resin, reinforcement, and filler, b) ratio of individual material components, c) orientation of the reinforcing agent or inclusions, and d) processing or manufacturing conditions employed. Significant environmental parameters are: gas enthalpy; gas chemical composition and reactivity; and c) mechanical forces of pressure, shear and deceleration. The results of an analysis of the heat and mass parameters of plastics ablation indicate that the material absorbs and blocks (cont.)

1-1278. (Cont.)

heat by several different modes: a) internal conduction and storage of heat by the solid and gaseous materials, b) mass transfer in the boundary layer, c) radiative transport, d) phase transitions, e) chemical reactions, and f) convection in the liquid layer, if one exists. Material research reentry vehicles for flight testing of ablative thermal protective systems are discussed, and photographs of these vehicles are shown. Future reentry environments and associated material requirements are given. This expository analysis of reentry ablation provides a basic understanding of the behavior of plastic materials in aerothermochemical environments. It provides a wealth of technical information on the selection and improvement of ablative plastics intended for thermal protective systems of ballistic missiles, satellites and interplanetary reentry vehicles.

1-1279. ELASTOMERIC AND COMPLIANT MATERIALS FOR CONTACT WITH LIQUID ROCKET FUELS AND OXIDIZERS. Joseph Green and Nathan B. Levine. Thiokol Chemical Corp. Reaction Motors Div., Denville, N. J., ASD TR 61-76, Pt. I. Sept. 1961. 46p. Contract: AF 33(616)-7227, Proj. no. 7340, Task no. 73405. 16 refs. A62-1052, pt. 1.

Various techniques have been employed in efforts to provide elastomeric composites suitable for use in contact with hydrazine-type fuels, nitrogen tetroxide, and chlorine trifluoride. Through the use of compounding studies and investigations of resinous and metallic coating systems, several elastomeric materials have been recommended for field testing in contact with hydrazine-type fuels and nitrogen tetroxide. A polyethylene coating has been applied to an elastomeric O-ring. The elastomer base has been protected from $NO_2 \rightleftharpoons N_2O_4$ for 24 hrs by this coating. Preliminary investigations have been initiated for development of elastomeric composites which are compatible with chlorine trifluoride.

1-1280. HIGH MODULUS GLASS FIBERS FOR REINFORCED PLASTICS. George P. Peterson. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., WADD TR 60-735. Sept. 1961. 80p. illus. Contract: AF 33(616)-5500, Proj. no. 7340, Task no. 73400. A62-399.

This report is a compilation of papers and the general discussion presented at the Aeronautical Systems Division--University of Dayton joint meeting on High Modulus Fibers for Reinforced Plastics, 12 October 1960, Miami Hotel, Dayton, Ohio. The papers, for the most part, review work completed or in process under Directorate of Materials and Processes research and development programs. The following papers are included in this report:

Properties of High Modulus Reinforced Plastics, by George P. Peterson.
High Modulus Glass Fibers for Structural Plastics, by Ralph L. Tiede.
Processing and Fabrication Techniques for Reinforcing Plastics With YM-31A Fibrous Glass, by Allan B. Isham.
Structural Efficiency of Sandwich as Affected by Elastic Modulus and Weight of Facing, by E. W. Kuenzi.
Safety Precautions for Handling and Fabrication of High Modulus Glass Fibers for Structural Plastics, by L. J. Schafer and L. H. Miller.

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Potential Uses of High Modulus Glass Fibers, by P. Layton.
Marketing and Availability of High Modulus Glass Fibers, by W. M. Keller.

I-1281. HIGH TEMPERATURE RESINS, ANALYSIS OF PROCESS PARAMETERS, AND EVALUATION PROCEDURES FOR FILAMENT WOUND COMPOSITES. PART I. HIGH TEMPERATURE RESINS. J. Vernon Kindall, Frank J. Riel, et al. Narmco, Inc., San Diego, Calif., WADD TR 60-791, Pt. I. Aug. 1961. 176p. illus. Contract: AF 33(616)-6737, Proj. no. 7340, Task no. 73402. AD 999 999. A61-11690, pt. 1.

The main objective of this phase of the program was to develop a superior, heat-resistant, filament-winding resin, effective at 500° F, and for short time exposure, at 750° F. Hoop tension and interlaminar shear tests, carried out on a unidirectional circular glass fiber-resin composite (a Naval Ordnance Laboratory (NOL) type ring) were used as the chief means of resin screening and evaluation. Heat-stable epoxy, epoxy novolac, temperature-resistant polyester, silicone-phenolic, and silicone resins were studied to establish the quality of existing filament-winding resins and to furnish a basis for resin modification and synthesis. Two synthesized epoxy resins, vinyl-resorcinol-diglycidyl-ether and allyl-diglycidyl-cyanurate gave tensile and shear strengths essentially comparable to the best commercially available resins at temperatures to 750° F. At room temperature, most commercial and synthesized resins evaluated gave essentially equivalent tensile and (cont.)

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shear strengths. Many were eliminated, however, when evaluated at 500° F and 750° F. The tensile strength of the glass component of the rings was investigated by static load testing at room temperature, 500° F and 750° F. An average tensile strength of 282,000 psi was obtained for strands of ECG 150-1/0 PO16 glass yarn at room temperature, 235,000 psi at 500° F, and 186,000 psi at 750° F. The strength of glass-roving specially protected with resin at the bushing was slightly superior to the standard glass yarn. By comparing glass tension-stress values obtained with NOL-type rings with the static tensile strength data, it was shown that many resins at room temperature, and a few at 500° F and 750° F, bound the glass fibers together in such a fashion as to allow nearly the ultimate tensile strength of the glass component itself to be realized. Dow's epoxy novolac, DEN 438/MNA/DMP-30, resin system was selected as the best over-all, temperature-resistant, filament-winding resin. NOL-type filament wound rings, fabricated with this resin gave a hoop tensile strength (ring stress) of 157,000 psi at room temperature, 125,000 psi at 500° F, and 84,000 psi at 750° F.

1-1282. MICROSTRUCTURE OF ABLATIVE PLASTIC CHARS.
Samuel A. Marolo. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., WADD TR 60-856. Aug. 1961. 75p. illus. Proj. no. 7340. 23 refs. A61-10400.

The behavior of ablative plastics in very high temperature environments is a subject of current investigations. The interaction of organic resins and fibers contained in reinforced plastics with hyperthermal environments may result in the formation of a residual surface char, which forms an effective barrier between the virgin plastic and the high temperature environment. Surface chars from air plasma exposed conical plastic models served as the experimental materials.

1-1283. A NEW CONCEPT FOR REENTRY WINDOWS. Sidney Allinikov and Fred W. Forbes. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., ASD TR 61-181. Sept. 1961. 44p. illus. Proj. no. 7381; Task no. 73810. A62-397.

A new concept for windows of re-entry vehicles is presented in this report. It has been demonstrated that this window will allow vision at all times including the re-entry period and that moderate temperatures on the window may be maintained permitting the use of conventional transparent material such as Pyrex. A disc containing slots or holes and made of Transite, an insulating material, is mounted in front of the window. When rotated at a sufficient speed, good vision and photographic reconnaissance are possible. The use of the insulating, slotted disc, the rotation of the disc, and the injection of a coolant gas between the disc and the window result in relatively moderate temperatures on the window. Visual photographic tests of the window as well as feasibility tests of the concept are discussed. The test environment was provided by a J-75 engine with afterburner, and the Aeronautical Systems Division's High Temperature Hypersonic Gasdynamics Facility. Optimum materials, designs, and possible applications are suggested.

1-1284. THE PREPARATION OF CERTAIN HETEROCYCLIC POLYMERS BY AN ALTERNATING INTRAMOLECULAR-INTERMOLECULAR CHAIN PROPAGATION. George B. Butler, Charles F. Hauser, et al. Florida. Univ., Gainesville, ASD TR 61-237, Pt. I. Aug. 1961. 40p. Contract: AF 33(616)-6887, Proj. no. 7023; Task no. 73666. 27 refs. A61-11396, pt. 1.

Several vinyl and divinyl phosphines and phosphine oxides have been prepared. A polymer of diphenylvinylphosphine oxide and possibly co-polymers of divinylphenylphosphine and divinylphenylphosphine oxide with maleic anhydride have been prepared. An attempt to polymerize diallylphenylphosphine by a free radical mechanism was unsuccessful. The attempted copolymerizations of divinylphenylphosphine with vinyl ethyl ether, vynyltrimethyl silane, yielded negligible quantities of polymer. Diallylphenylphosphine has been prepared via a modification of the procedure reported earlier. A yield of 45% was obtained from the latter procedure. Sodium hydroxide degradation of poly-(diallylphenylethyl phosphonium bromide) has resulted in the formation of poly-(diallylethylphosphine oxide). Poly-(diallylphenylphosphine oxide) has also been prepared by a similar type of degradation. A number of phosphonium salts and their polymers have been prepared and characterized. The use of the Wittig reaction to prepare olefins from straight chain aldehydes such as butanal is being investigated.

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Short condensation times between the aldehyde and the carbanion of the phosphonium salt appear to yield olefins where previously no such product could be obtained. Two methods for the preparation of allyldimethylvinylsilane have been developed. Poly-(diallyldiphenylsilane) has been prepared in 54% yield for molecular weight studies. Molecular weights range from 40,000 - 240,000. Attempts to polymerize allyldimethylvinylsilane by use of the Ziegler catalyst have resulted in oils. Copolymerization of tetravinylsilane with maleic anhydride has been carried out to yield a solid for which the characteristic vinyl band in the infrared region is absent. Similar results have been obtained for the copolymerization of tetravinyltin with maleic anhydride. An alkali soluble copolymer of divinyldimethyltin with maleic anhydride has been prepared.

I-1285. RESEARCH ON INORGANIC POLYMER SYSTEMS. Allen L. McCloskey, William G. Woods, et al. United States Borax Research Corp., Anaheim, Calif., WADD TR 60-911. Apr. 1961. 278p. illus. Contract: AF 33(616)-7303, Proj. no. 7340, Task no. 73404. 157 refs. A61-11143.

This report covers investigations by U. S. Borax Research Corporation and certain university subcontractors on the chemistry of thermally stable polymers. Systems based on B-B, B-N, Al-O and Al-N bonding have been studied at U. S. Borax; subcontractors have investigated polymers based on tin, pi-bonded polymers and alternate inorganic polymer systems. Thermally stable $(B\text{-}B)_n$ polymers with promising physical and chemical properties have been prepared by the thermal treatment of tetra(amino)diborons, particularly tetra(anilino)diboron, and by the reactions of tetra(dimethylamino)diboron with phenylenediamines. Investigations on the preparation of stable, thermoplastic B-N resins by thermal resinification of selected borazoles have been completed. Several methods, including a promising transaminative condensation technique, for the synthesis of several types of B-N bonded polymers have been studied. Two promising methods for the preparation of difunctional borazole monomers were developed. Research on Al-O and Al-N systems was directed toward the preparation of stable Al-O, Al-O-Si-O, Al-O-B-O and Al-N polymers. Two condensation

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polymerization techniques were utilized to prepare polymers having molecular weights of 1200 to 6000. The facile reaction of aluminum alkyls with active hydrogen compounds has proven to be a useful preparative technique for various prototypes, monomers and polymers. A program was initiated to evaluate promising new polymers as bonding agents in laminate composites.

1-1286. RESEARCH ON THE SYNTHESIS OF THERMALLY PROTECTIVE MATERIALS FOR REENTRY ENVIRONMENTS. R. K. Carlson, B. A. Forcht, et al. Chance Vought Aircraft Inc., Dallas. Astronautics Div., ASD Quarterly Technical Report no. 2. 15 Sept. 1961. 49p. Contract: AF 33(616)-7947. A61-11369.

The primary program objective lies in the experimental synthesis and evaluation of new thermally protective materials for reentry applications. Multicomponent composite systems containing both an ablative filler and a structural substrate phase are currently under investigation. During the report period, porous carbonaceous substrates with "E"-glass, quartz, and graphite cloth reinforcement phases were fabricated and impregnated with a large number of organic and inorganic ablative fillers. Plasma arc evaluation of the material composite was initiated at Vought and an ASD contracted facility. Environmental conditions used were

Heat Flux	150 Btu/ft^2-sec
Enthalpy	3000 Btu/lb
Time	60 sec

The composites evaluated had in general, a low recession rate (0.001-0.0001 in./sec.), excellent thermal stability, and fair thermal insulation

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characteristics. Additional environmental studies under a wide variety of operating conditions will have to be conducted before complete material behavior criteria can be established.

1-1287. STUDY OF THERMAL RADIATION WITHIN SOLIDS AND STUDY OF INTERNALLY ABLATING COMPOSITES. PART II, VOLUME I--INTERNALLY ABLATING COMPOSITES.
Franklin A. Vassallo. Cornell Aeronautical Lab., Inc., Buffalo, WADD TR 60-697, Pt. II, Vol. I. Sept. 1961. 92p.
Contract: AF 33(616)-6886, Proj. no. 4776, Task no. 6.
A61-9697, pt. 2, vol. 1.

The work reported concerns an analysis of composite materials designed so that high heat flux at one face will cause one phase to act as an energy absorbing material (by melting, vaporizing, or decomposing and thereby flowing out through the heated surface) and in so doing, cool the other phase and maintain its dimensional stability. This combined process is referred to as internal ablation. The results of numerical analysis have been generalized and expressed by dimensionless groups whose relations are shown in chart form. The initially considered case of one-dimensional heat flow into a semi-infinite body has been followed by a similar treatment for the finite body. The curves prepared allow a computation of the duration of the two-phase body (limited by melting of the heated face of the matrix or by removal of all of the ablative phase) for many combinations of material and environmental characteristics. In a typical example given as an illustrative

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calculation, the duration of the two-phase body is several times greater than that of the non-porous matrix. Experimental tests are described and their results generally confirm the results of the analysis.

1-1288. SYNTHESIS AND EVALUATION OF THERMALLY STABLE POLYMERS. G. P. Brown, A. Goldman, and C. D. Doyle. General Electric Co., Schenectady, N. Y., WADD TR 61-255. June 1961. 88p. Contract: AF 33(616)-7076, Proj. no. 7340; Task no. 73404. 85 refs. A61-11757.

PHASE I--POLYMER SYNTHESIS. Poly-m-phenoxylene has been synthesized with number-average molecular weights approaching 4000 and, in one case, a weight-average molecular weight of 6800. The synthesis routes studied have included self-condensation of alkali metal salts of m-bromophenol (successful), condensation of salts of resorcinol with m-dibromobenzene, and self-condensation (dehydration) of resorcinol (the latter two unsuccessful). In addition to polymer, four syntheses provided small amounts (< 1%) of crystalline material indicated as being cyclic oligomers (trimer and tetramer presumably). Study of a variety of reaction conditions indicates that anhydrous conditions are absolutely essential in order to minimize carbon-carbon coupling. Purity of the starting material m-bromophenol is probably the most important cause for failure, as yet, to achieve higher molecular weights, but that low rates of reaction under heterogeneous conditions may also adversely affect molecular weights by promoting cyclization reactions.

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PHASE II--POLYMER EVALUATION. The results of concluding thermal stability studies and preliminary heat-softening studies are presented. Topics treated in the major section on thermal stability include: methods of kinetic analysis of thermogravimetric data illustrated for zero-order (octamethylcyclotetrasiloxane) and first-order (polytetrafluoroethylene) volatilization; effects of varying sample geometry in thermogravimetry, and thermoparticulate analysis as a means of observing incipient and vestigial volatilization. Topics treated in the major section on heat-softening include methods of observing heat-softening in powdered samples, as well as such underlying causes of heat-softening as relations and thermodynamic transitions. The methods considered include: differential thermal analysis, volume dilatometry, x-ray and electron diffractometry, methods of observing mechanical, electrical and nuclear magnetic relation effects, and a new heat-softening test. As a part of the study of nuclear magnetic resonance, some styrene-divinylbenzene copolymers of various degrees of cross-linking are compared.

1-1289. SYNTHESIS OF FIBER REINFORCED INORGANIC LAMINATES. Edward M. Clausen, Doris M. Krumwiede, et al. Illinois. Univ., Urbana, WADD TR 60-299, Pt. II. July 1961. 63p. Contract: AF 33(616)-6283, Proj. no. 7340. A61-11216, pt. 2.

High-temperature demands in air and space vehicle programs have necessitated studies directed toward the use of inorganic materials as the matrix for reinforced composites. In the first year's research, phosphate-bonded, complex oxide bodies with definite evidence of $AlPO_4$ and $FePO_4$ phases were developed with elastic moduli on the order of 0.3×10^6 psi, and flexure strengths up to 10,000 psi. Inorganic matrix materials of this type, unfortunately, are corrosive to vitreous reinforcements. The objectives of this second year's research were the study of compositional and processing variables on matrix strength, the explanation of the observed deformation of matrix bodies, and research on protective fiber coatings. Type of bonding acid used, premilling time of dry raw materials, reacting temperature, and milling time of reacted materials were considered as variables affecting matrix strength. Reactions occurring during drying and firing, and the mechanism of deformation were investigated using x-ray, light microscopy, and electron microscopy techniques. Deformed specimens were thought to

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contain concentrated areas of Al_2O_3 crystals and a slightly more amorphous matrix. One of these differences might be the cause of deformation. The following were considered as coatings for glass fibers: tin oxide, vapor-deposited antimony oxide and molybdenum trioxide, organic-inorganic oxides, and liquid silver. With the exception of the vapor-deposited coatings, these materials appeared to offer the fiber some protection. The strength and corrosive effect of matrices on Al_2O_3, TiO_2, and ZrO_2 rods were examined. Modulus of rupture values for E38 matrix bars containing Al_2O_3 rods were the highest.

1-1290. SYNTHESIS OF NEW PLASTIC MATERIALS FOR ROCKET NOZZLES. Norman Bilow, Richard I. Akawie, et al. Second Progress Report, 1 June-31 Aug. 1961. Hughes Aircraft Co., Culver City, Calif. Components and Materials Lab., Rept. no. P61-14. 15 Sept. 1961. 69p. Contract: AF 33(616)-8037. A61-11372.

Utilizing the typical nozzle design described in the first progress report, aerodynamic shear has been related to the longitudinal position of a rocket exhaust gas stream in a rocket nozzle. Standard free energies of reaction have been calculated for approximately 240 different reactions at temperatures of 1000°, 2000°, 3000°, and 4000° K. These calculations have been made on materials which are potentially useful in composite rocket nozzles in order to gain insight into methods for controlling degradation and promoting desirable reactions. Several polymers such as polyphenyl and polyphenylenesilane have been prepared for evaluation as rocket nozzle matrices. They were, however, too highly crosslinked to be useful molding compounds. Several intermediates useful in preparing other polymers have also been synthesized. These include acetylenedicarboxylic acid diamide, diaminomaleonitrile, oxalyl chloride, oxalyl bromide, 5,6-dicyanopyrazine-2,3-dicarboxylic acid, dicyanoacetylene, tetracyanobenzene, and cobalt

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carbonyl mercury complex. The char forming characteristics of various metal boride-, carbide-, and nitride-filled phenolic resins have been examined. Titanium diboride, molybdenum diboride, and boron carbide in that order appear to have outstanding char forming capabilities.

1-1291. SYNTHESIS OF SEMI-INORGANIC FLUORINE POLYMERS. PART III. PERFLUOROALKYLTRIAZINE POLYMERS. STUDIES OF INTERMEDIATE POLYMER FORMATION, MECHANISM OF POLYMERIZATION AND CATALYTIC TRIMERIZATION OF PERFLUOROALKYL NITRILES.
Henry C. Brown. Florida. Univ., Gainseville, WADC TR 59-272, Pt. III. Aug. 1961. 75p. Contract: AF 33(616)-6887, Proj. no. 7023, Task no. 73666. A61-11397, pt. 3.

The formation of an intermediate polymer from the reaction of perfluoroglutaronitrile with perfluorobutyramidine has been studied both in solution and in bulk. This intermediate product, by deammonation under further heat treatment, has been shown to produce the perfluoroalkyl-triazine polymers in thin, coherent sheets that are elastic and thermally stable. A study of the volatile products produced under controlled heating of the intermediate polymer has been initiated. N'(Perfluoroacylimino)perfluoroalkylamidines, the initial intermediates in the deammonation of perfluoroalkylamidines to tris(perfluoroalkyl) sym. triazines, have been studied in more detail as a part of the overall mechanism of triazine formation. Revised preparative procedures, visible and ultra-violet spectra, analytical procedures and hydrolysis products are described. Deuteration of N-H

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bonds and spectral shifts are discussed. A quantitative study of the catalytic trimerization of perfluoroacetonitrile and polymerization of perfluoroglutaro-nitrile is presented. The cotrimerization of perfluoroaceto-nitrile with organic aromatic nitriles is shown to be much more efficient with the basic catalyst ammonia than with acidic catalysts.

1-1292. TWO-PHASE MATERIALS. Games Slayter. Sci. American, vol. 206, no. 1, Jan. 1962, p. 124-34.

Composite materials, notably glass fibers embedded in a plastic matrix, have come into wide use in the last two decades. This type of material has the inherent virtue of being the strongest engineering material available on a weight-for-weight basis. Its specific strength is 2.5 times that of any homogenous material. This high strength derives from the two-phase principle of material structure and strength. The high-strength structure usually constitutes the larger portion of the total mass and is dispersed in a matrix formed by the low-modulus substance. Under applied force, the low-modulus substance stretches and deforms, distributing the stress to the high-strength component. Isolation of the imperfections present in the individual crystals or fibers of the high-strength material prevents the propagation of cracks from these imperfections. Text and diagrams show examples of natural and synthetic two-phase materials, such as bamboo, Damascus steel swords, and many modern metal alloys, nylon yarns, etc. Graphic comparisons are made between the specific strengths of cross laminates, parallel laminates, steel, and aluminum. Some of the uses of the two-phase glass fiber materials are outlined. The greatest promise in the application of the two-phase concept lies in the prospective utilization of oxides as structural materials; to date the brittleness of oxides has prevented their use.

SECTION H - ADHESIVES

No entries are made in this issue.

1-1293. DEVELOPMENT OF PARTIALLY VOLATILE BRAZING FILLER ALLOYS FOR HIGH-TEMPERATURE APPLICATION AND RESISTANCE TO OXIDATION. Nikolajs Bredzs, John F. Rudy and Harry Schwartzbart. Illinois Inst. of Tech., Chicago. Armour Research Foundation, WADD TR 59-404, Pt. II. June 1961. 53p. illus. Contract: AF 33(616)-6882, Proj. no. 7351, Task no. 73516. A61-10557, pt. 2.

The mechanical properties and resistance to oxidation of 304 stainless steel joints brazed with the following four experimental filler alloys, containing volatile constituents, have been determined: Alloy A: 61% Ni-39% In; Alloy C: 65% Ni-17% Cr-9% In-9% Si; Alloy I: 33% Ni-33% Cr-17% In-17% Ge; Alloy N: 35% Ni-24% Cr-26% In-15% Ge. A special brazing technique was developed for brazing these joints. The special technique involved: 1) a method of preparation of the alloy so that a homogeneous and desired composition was available to fill the joint capillary and 2) a method of volatilizing the melting point depressant to avoid the difficulty of "boiling," while still obtaining sufficient volatilization to provide the required higher remelt temperature and good high-temperature properties. Miller-Peaslee type specimens brazed by this technique were used for the determination of joint strength at room temperature and elevated temperatures up to 1900° F. The highest shear strength of all four alloys was exhibited by the 65% Ni-17% (cont.)

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Cr-9% In-9% Si alloy. The oxidation resistance of all joints brazed with the four experimental filler alloys was excellent. Some of the joints brazed with the 51% Ni-39% In alloy showed considerable signs of oxidation after exposure to the open air for 500 hrs at 1600° F.

1-1294. **REVIEW OF RECENT DEVELOPMENTS IN METALS JOINING.** J. J. Vagi, W. J. Lewis, and H. W. Mishler. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC memo 140. 6 Dec. 1961. 8p. 12 refs. A61-11548.

This memorandum summarizes recent major developments in the technology of metal joining. The titanium-base alloys are considered with respect to arc welding, ultrasonic welding, and electron-beam welding, since the fracture toughness studies on titanium alloys appear promising for solid-fuel rocket-motor cases. Welding methods and techniques are also discussed for columbium-base alloys, tungsten and molybdenum-0.5 Titanium alloy, rocket-motor cases, and armor steels. Finally, the weight saved by flash welding is analyzed for various materials.

SECTION J - CHEMICAL AND PHYSICAL PROPERTIES OF MATERIALS

1-1295. **GROWTH AND MECHANICAL PROPERTIES OF FILAMENTARY SILICON CARBIDE CRYSTALS.** Luke A. Yerkovich and Henry P. Kirchner. Cornell Aeronautical Lab., Inc., Buffalo, WADD TR 61-252. Aug. 1961. 32p. Contract: AF 33(616)-7005. 17 refs. A61-11219.

In this investigation, silicon carbide whiskers were grown under various experimental conditions. The strength and modulus-of-elasticity of several whiskers were determined at room temperature. Methods of heating the whiskers for high-temperature measurements were investigated. The specific gravity of the whiskers has been inferred from measurement of the unit cell dimensions by X-ray diffraction patterns. Silicon carbide whiskers were grown by pyrolysis of methyltrichlorosilane in hydrogen. In some cases, dense growths of whiskers from 1.2-1.5 cm in length and from 2-5μ in diameter were observed. The longest whisker obtained, thus far, was 5 cm in length. The tensile strength of these whiskers ranges from 100,400 to 1,650,000 psi. The elastic strain at failure varied from 0.41-1.10% and the observed values of elastic modulus varied from 12,700,000 to 123,300,000 psi. These results indicate that silicon carbide whiskers can be strong, high-modulus-of-elasticity materials. Much research remains to be done to improve the methods of measurement and to define the conditions of measurement and the types of whiskers that will give the best performance as structural materials.

1-1296. **MEASUREMENT OF DISPLACEMENTS IN CONTACT-STRESS EXPERIMENTS.** G. E. Bowie. Minnesota. Univ., Minneapolis, ASD TR 61-450. Oct. 1961. 32p. Contract: AF 33(616)-6828, Proj. no. 7351, Task no. 73521. A62-1056.

A major part of the instrumentation for contact-stress investigations being carried out at the University of Minnesota has the function of providing displacement measurements in the microinch range. This report describes a modified phonograph-type displacement pickup and an interferometer for calibrating it. In addition, a piezoelectric driving transducer used to load spheres upon which experiments are performed, a capacitance-type displacement pickup, and modifications of an Instron testing machine upon which the apparatus is mounted are described.

1-1297. THE PREPARATION OF ORGANOMETALLIC DERIVATIVES OF INORGANIC "BENZENOID" COMPOUNDS. Dietmar Seyferth, Walter Freyer, and Gunter Raab. Massachusetts Inst. of Tech., Cambridge. Dept. of Chemistry, ASD TR 61-1, Pt. I. July 1961. 18p. Contract: AF 33(616)-7124, Proj. no. 7023, Task no. 73666. A61-11395, pt. 1.

The attempt to prepare silyl-substituted phosphazenes by the reaction of silyl-substituted tetrachlorophosphoranes with ammonium chloride was not successful because one of the key reactions--that between trimethylsilyl-methyldichlorophospine and chlorine--failed to go in the desired direction: chlorinolysis of the silicon-carbon bond, rather than formation of trimethyl-silylmethyltetrachlorophosphorane, was observed. A successful synthesis of the hitherto unknown reagent, perfluorovinyllithium, has been developed. The exchange reaction occurring between phenyl- and n-butyllithium and perfluoro-vinyltin compounds in ether or in pentane gives perfluorovinyllithium in 40-45% yield. β-chloro-β',β''-bis(trimethylsilylmethyl)-N, N', N''-tri-methylborazene was prepared in 47% yield. This compound will serve as an intermediate in future studies. The following new compounds have been synthesized during this work: Bis(trimethylsilylmethyl)mercury; Tetrakis (trimethylsilylmethyl) lead; Tris(trimethylsilylmethyl) lead chloride; Trimethylsilylmethyldichlorophosphine; Perfluorovinyllithium; β-chloro-β', β''-bis(trimethylsilylmethyl)-N, N', N''-trimethylborazene.

1-1298. THE P-T-X PHASE DIAGRAM OF THE SYSTEM Sn-S. W. Albers and K. Schol. Philips Research Repts., vol. 16, no. 4, Aug. 1961, p. 329-42, 29 refs.

The phase equilibria solid-liquid-vapor are determined for the system Sn-S. Two maxima are found in the T-X_L diagram, one at the composition of SnS, the other at the composition of SnS_2. The compound SnS has a maximum melting point of 881.5± 2° C at a sulphur pressure of 25 mm Hg(0.033 atm), and SnS_2 has a maximum melting point of about 870° C at a sulphur pressure of about 40 atm. A range of liquid immiscibility exists between about 10 and 47 at.$^{o}/_{o}$S and possibly also between about 70 and 90 at.$^{o}/_{o}$S. A new compound is found with a probable composition of Sn_3S_4.

1-1299. **STUDY OF GERMANIUM BY TRANSPARENCY IN INFRARED LIGHT; DOUBLE REFRACTION OF SILICON AND GERMANIUM.** C. Grandjean. Philips Research Repts., vol. 16, no. 4, Aug. 1961, p. 343-55, 9 refs.

The paper begins with the description of the apparatus used, essentially a Nipkov disk and a lead-sulphide cell, capable of low-definition examination of silicon and germanium in linearly or circularly polarized light. Subsequently, some results obtained with this apparatus on silicon and germanium are given. Finally, the principle and the results of measurements of the photo-elastic constant of silicon ($K = 1.97 \pm 0.05$) in [111] direction and germanium ($K = 0.026 \pm 0.04$) in [100] direction are defined; knowledge of these constants makes it possible to state the minimum stresses which can be detected in silicon and germanium.

1-1300. **STUDY OF LOW TEMPERATURE MECHANICAL PROPERTIES OF METALS AND SOLIDIFIED GASES.** Final report, 22 Jan. 1957-21 Jan. 1961. Virginia. Univ., Charlottesville. Dept. of Physics. 1 Mar. 1961. 133p. Contract: DA-36-034-ORD-2219. AD 253 139. A62-15.

This report consists of the following papers which describe mechanical properties of metals and solidified gases at low temperature and methods used for determining these properties:

Studies of Metals at Low Temperature, by J. W. Beams.
Mechanical Properties of Thin Films of Gold and Silver, by J. W. Beams.
Studies of Solidified Gases at Low Temperature, by John W. Stewart.
Compression and Densities of Four Solidified Hydrocarbons and Carbon Tetrafluoride at 77° K, by John W. Stewart and Ralph I. La Rock.
Phase Transitions and Compressions of Solid CH_4, CD_4 and O_2, by J. W. Stewart.
Application of Indium Resistance Thermometry, by John W. Stewart.
Compression and Phase Transitions of Solid NH_3, SiF_4, H_2S, and CF_4, by John W. Stewart.

1-1301. THERMAL CONDUCTIVITY OF SEMICONDUCTIVE SOLIDS; METHOD FOR STEADY-STATE MEASUREMENTS ON SMALL DISC REFERENCE SAMPLES. D. R. Flynn and H. E. Robinson. Interim Technical Report, 23 Feb. 1959-31 Mar. 1961. National Bureau of Standards, Washington, D. C., Rept. no. 7135. 29p. A62-380.

An absolute cut-bar method of measuring the thermal conductivity of solids suitable for small specimens of semiconductive materials is described. Measurements have been made at temperatures from 100° to 800° C on Pyrex, Pyroceram, and a nickel-chrome alloy, and representative tentative results are given. The data for the nickel-chrome alloy, over the common temperature range 120° to 600° C, agree with the smoothed data from measurements made on the same material by an independent absolute method, with a standard deviation of 0.7%. The data for Pyrex and Pyroceram may be subject to errors because of the uncertainties introduced by thermal contact resistance at the surfaces of the specimens. It is shown that the use of a matched guard in a cut-bar apparatus does not reduce extraneous heat exchanges between the bars and specimen and the surrounding powder insulation to the small magnitude desirable for good accuracy of measurement. A mathematical analysis of the system indicates a superior guarding condition which greatly reduces these extraneous heat flows, and which was used in the (cont.)

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measurements mentioned. Using the knowledge acquired by these investigations, a final model of the apparatus is being built for measurements on small specimens (1/2-in.. by 1-in. diameter discs) at temperatures in excess of 1200° C.

1-1302. THERMAL CONDUCTIVITY OF SEMI-CONDUCTIVE SOLIDS; METHOD FOR STEADY-STATE MEASUREMENTS ON SMALL DISK REFERENCE SAMPLES. D. R. Flynn. Technical Progress Report, 1 Apr. -30 June 1961. National Bureau of Standards, Washington, D. C., Rept. no. 7323. 4p. A62-381.

The salient features of the final model of an absolute cut-bar apparatus suitable for thermal conductivity measurements on small solids at temperatures up to 1200° C or higher are described. The high temperature portions of the apparatus which will contact the specimen are 60% platinum-40% rhodium alloy. The remaining high temperature structural portions are high purity (99+%) alumina. Construction of the apparatus was completed and initial check measurements started. A brief summary of initial measurements to be made with the apparatus is given.

1-1303. THERMAL CONDUCTIVITY OF SEMICONDUCTIVE SOLIDS; METHOD FOR STEADY-STATE MEASUREMENTS ON SMALL DISK REFERENCE SAMPLES. D. R. Flynn. Technical Progress Report, 1 July-30 Sept. 1961. National Bureau of Standards, Washington, D. C., Rept. no. 7367. 25p. A62-382

Thermal conductivity measurements were conducted over the temperature range 200° to 1200° C on the bar of 60% platinum-40% rhodium alloy from which the hot and cool contacting bars of the high-temperature apparatus are to be fashioned. The tentative results, not yet corrected for individual thermocouple variations, plot smoothly from 0.57 w/cm-C at 200° C to 0.79 w/cm-C at 1200° C. A paper "Thermal Guarding of Cut-Bar Apparatus," which was presented at the Invitational Conference on Thermal Conductivity Methods held at Battelle Memorial Institute, Columbus, Ohio, 26-28 Oct. 1961, is reproduced following the main body of this report.

1-1304. THERMODYNAMICS OF INTERSTITIAL SOLID SOLUTIONS. Larry Kaufman. Manufacturing Laboratories, Inc., Cambridge, Mass., ASD TR 61-445. Oct. 1961. 61p. illus. Contract: AF 33(616)-6788, Proj. no. 7350, Task no. 73500. 47 refs. A62-1054.

The thermodynamics of interstitial solid solutions in terms of the contributions of positional and vibrational entropy and zero point enthalpy has been considered in detail for ideal and restricted interstitial solutions. The results have been applied to calculation of phase equilibria in interstitial iron-carbon alloys at one atmosphere and high pressure. Comparison with observations on kinetics of the bainite reaction and high pressure equilibria action yields good agreement. A method evolved for computing the entropy of solutions and intermetallic compounds from 0° K to the melting point has been applied to 35 NaCl type compounds (including high melting carbides, oxides and nitrides). These computations compare favorably with experimental data. A study of the interstitial solutions in the titanium-oxygen system indicates that the high temperature stability of the h. c. p. solution is due to the enthalpy of formation.

1-1305. TWENTIETH BIMONTHLY PROGRESS REPORT ON THE THERMOSTATIC AND TRANSFER PROPERTIES OF HYDROGEN. 1 May-1 July 1961. National Bureau of Standards. Boulder Labs., Boulder, Colo., Rept. no. 6788. 65p. A61-11379.

The overall objective of this project is the preparation of a thermodynamic network for para hydrogen from 17° to 100° K and from 2 to 350 atm. The following tables are compiled: 1) Para hydrogen properties for ideal gas stated at one atmosphere (Table 3); 2) second and third virial coefficients and derivatives (Tables 4 and 5); 3) densities of saturated para hydrogen vapor (Table 6); and 4) pressure-density relations for saturated liquid (Table 7). Finally, the fully corrected Pressure-Volume-Temperature data tables 45-94 are presented for permanent record.

1-1306. USE OF DILATOMETRY FOR MEASURING POLYMERIZATION RATES. W. E. Gibbs and J. T. Murray. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., WADD TN 60-271. June 1961. 25p. illus. Proj. no. 7340, Task no. 73404. A61-11759.

The determination of reaction rates in the polymerization of vinyl type monomers presents difficulties particularly when the quantity of monomer available is limited and when very good accuracy and precision is required. This was the situation encountered when the study of the reaction kinetics of various diolefinic monomers was initiated by the authors of this communication. A consideration of the various methods of following polymerization reaction rates led to the selection of dilatometry as the only reasonable approach to the circumvention of the difficulties noted above. This method, with some significant alterations in the construction of the dilatometers and in the procedures generally followed, yields data with the required accuracy and precision even when very small quantities of monomers are used. A comparison of the reaction rate values obtained here with that available from other procedures, as well as with values available in the literature, gave excellent agreement. The monomer systems studied include: styrene in toluene, dimethyl-2, 2''-dimethylene pimelate in toluene, and methacrylic

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anhydride in N, N-dimethylformamide. From the results obtained, it appears possible to extend the technique to give accurate and precise data with samples of monomers of less than 0.25 grams per polymerization.

SECTION K - EFFECT OF NUCLEAR RADIATION ON MATERIALS

No entries are made in this issue.

SECTION L - FLUIDS

1-1307. ACCELERATED STORAGE STABILITY TESTS. Eldred N. Cart. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., ASD TR 61-144. Sept. 1961. 46p. illus. Proj. no. 3044, Task no. 30169. 6 refs. A62-398.

The storage life of MIL-L-7808 oils has been improved by the use of amine type additives. This report describes the accelerated storage tests used to arrive at qualification limits. The time-temperature relationships for the storage life of MIL-L-7808 oils are given. From these relationships, the storage life can be estimated at any temperature from data at one given temperature. Regardless of the mechanism responsible for oil deterioration in storage (oxidation and/or hydrolysis), a test method is available for predicting a storage life at any temperature up to 260° F, the highest temperature investigated. The oven test is satisfactory for a batch acceptance test. However, additional work is needed to improve the reproducibility between various laboratories, particularily the wide difference between Esso and ASD (Esso being almost 3 times more severe). Precise temperature control is very important at these high oven temperatures and for the short times involved. Methods other than an oven for maintaining the desired temperature may be investigated.

1-1308. ADVANCED HEAT TRANSFER FLUIDS. L. J. Martin, C. W. Mell, and J. T. Milek. Hughes Aircraft Co., Fullerton, Calif. Ground Systems Group, WADD TR 61-186. July 1961. 429p. illus. Contract: AF 33(616)-7109, Proj. no. 7340, Task no. 73408. A61-11735.

An electronic coolant heat transfer study project is described in detail and test results presented in a series of graphs and tables. The project studied a wide range of organic fluids from -80° F to 400° F. Loop tests were performed only on those candidate fluids which passed screening and supplementary tests. Extensive vendor contacts resulted in focusing attention on relatively unknown materials; however, some commercial fluids were found to meet the requirements also. Silicone fluids appear to be the most promising and some of them met the requirements (viscosity, flash and fire points, dielectric) over the temperature range of -80° F to 400° F. A simple dynamic loop apparatus was devised and built to "punish" the electronic coolant fluids from -80° F to 400° F and permit an indication of the thermal chemical-dielectric-time stability required of these coolants in present and future electronic devices and equipment used in ground-based, ship-based and satellite vehicles. The program also included an extensive literature survey on electronic coolants, electronic equipment cooling, heat transfer, dielectric properties and stability, thermal stability, test methods and

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apparatus, liquid metals and fused salts for liquid phase and liquid-vapor cycle cooling. Five fluids were found to meet the requirements for cooling electronic equipment in the temperature range of -80° F to 400° F. Several other fluids almost meet the requirements and some of these can be modified to pass the specifications and operational requirements. The extensive literature survey showed that other investigators found the same general type of chemical compounds to be the most satisfactory, namely, the silicones and closely related structures.

1-1309. HEAT CAPACITY AND THERMAL CONDUCTIVITY OF LUBRICATING OILS AND HYDRAULIC FLUIDS. Donald C. Trop. Wright Air Development Center, Wright-Patterson AFB, Ohio. Aeronautical Systems Div., WADD TR 60-916. Aug. 1961. 44p. Proj. no. 3044; Task no. 73310. 11 refs. A61-11756.

The heat capacities of 36 lubricating oils and hydraulic fluids (polyphenyl ethers, disiloxanes, silanes, TMP esters, and silphenylene) were measured over a temperature range of 80° to 500° F by adiabatic and mixture methods. The "hot wire" and concentric cylinder types of thermal conductivity cells were fabricated and calibrated to measure the thermal conductivity of 18 lubricating oils and hydraulic fluids. Both methods are suitable for accurate thermal conductivity determinations. The data derived from thermal conductivity of fluids by the "Concentric Cylinder" and "hot wire" methods appear fairly comparable. Both methods agree on the conductivity of toluene at 100° F. The "hot wire" method agrees with the literature data on Dowtherm A in the temperature range of 200-400° F. The choice of methods is dependent on individual reference and material cost since both procedures are suitable for accurate thermal conductivity determinations. The agreement of adiabatic calorimeter and mixture calorimetry was better than 0.2%. The choice of methods would be the same as for thermal conductivity.

1-1310. PROPERTIES OF INORGANIC ENERGY-CONVERSION AND HEAT-TRANSFER FLUIDS FOR SPACE APPLICATIONS.
W. D. Weatherford, John C. Tyler, and P. M. Ku.
Southwest Research Inst., San Antonio, WADD TR 61-96.
Nov. 1961. 470p. Contract: AF 33(616)-7206,
Proj. no. 7381, Task no. 73812. A62-23.

This report is a complete revision of WADC TR 59-598. It is intended to serve as a properties handbook for various inorganic fluids which may have potential value as energy-conversion or heat-transfer fluids for space applications. The fluids are presented as three distinct classes: liquid metals, nonmetals, and gases. The liquid metals include mercury, cesium, rubidium, potassium, NaK (78), sodium, lithium, bismuth, and lead. The nonmetals include aluminum bromide, sulfur, and lithium hydride. The gases include argon, helium, and hydrogen. Data are presented, where available, up to temperatures ranging from 2300° F for mercury to 4500° F for lead, and for pressures ranging from less than one atmosphere to greater than twenty atmospheres. The enumerated properties include vapor pressure, density, viscosity, surface tension, electrical resistivity, thermal conductivity, specific heat, latent heats, enthalpyentropy relationships, melting point,

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critical properties, dielectric constant, ionization potential, magnetic susceptibility, thermal neutron cross sections, and corrosion characteristics. The characteristics of the various fluids are discussed, and the recommended values for the fluid properties are presented in tabular or graphical form with detailed documentation as to basis and source. In addition, background material including thermodynamic-cycle, heat-transfer, compatibility, and working fluid considerations is discussed. A summary of current research activities in this field is presented.

1-1311. RESEARCH ON SYNTHESIS OF 1000° F STABLE BASE FLUIDS. James W. Dale, Elizabeth A. McElhill, et al. Monsanto Research Corp. Boston Lab., Everett, Mass. WADD TR 59-95, Pt. III. Feb. 1961. 90p. Contract: AF 33(616)-6851, Proj. no. 8128, Task no. 73313. A61-11644, pt. 3.

With the ultimate objective of developing 1000° F thermally stable fluids, the work described in this report has continued under two broad divisions: fluorine and non-fluorine systems. In the fluorine program, effort has been concentrated on the synthesis of a limited number of perfluoropolyaromatic compounds, isolating as essential intermediates their perfluorocyclohexyl analogues which are of potential interest as thermally stable entities in their own right. Although the preparation of these perfluorocyclohexyl derivatives is simple in principle, making their thermal stability assessment significant by eliminating hydrogen-containing impurities and other perfluorinated structures requires considerable effort. For this reason, additional stability data on the perfluoro derivatives are meager, but that obtained confirms the high stability (1000° F) previously determined for representative compounds. Under the non-fluorine program, synthesis of model "building block" compounds, generally of aromatic structure, has continued with considerable

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new thermal stability data having been accumulated. This part of the program generally placed increasing emphasis on the synthesis and stability assessment of condensed and low polymeric systems made from such building blocks. Owing to different emphasis under the two programs, results of each are presented separately in two sections, Parts (I) and (II). Detailed individual summaries and discussion will be found at the beginning of each section.

SECTION M - FABRICATION METHODS

1-1312. ANALYTIC APPROACH TO STRETCH-FORMING CUTS TIME AND COST. Claude F. Morris. Space/Aeronautics, vol. 36, no. 6, Dec. 1961, p. 61-3.

Because of time limitations, General Dynamics/Fort Worth made an analysis of stretch-forming of aluminum parts. They set up a research program to derive the necessary equations. The analysis has been so effective that similar analyses are now being made on titanium alloys and stainless steels. Limiting effective stress and strain can be found from natural-log or true stress-strain curves based on tensile and compressive strength test specimens. By applying these limiting values to the equations expressing the forming operations, the formability limits of a material can be found. As a result of the analysis, many B-58 aluminum parts are being stretch-formed in one operation to net contour by tooling, using springback-allowance stretch-form dies and elongation control systems. Manhours per part have dropped sharply as a result, leading to savings of up to 50%.

1-1313. STRIPLAP METHOD OF ROCKET MOTOR CASE FABRICATION. T. B. Card. Interim Technical Engineering Report, 7 Sept.-6 Dec. 1961. Thiokol Chemical Corp., Brigham City, Utah. Wasatch Div., ASD TR 7-912 (II). Dec. 1961. 90p. illus. Contract: AF 33(600)-42961, Proj. no. 7-912. A62-387.

The completion of Phase I demonstrated the feasibility of the StripLap Method for the fabrication of rocket motor cases. The Purpose of Phase II is the fabrication of seven TU-193 (37.5 in. dia) rocket motor cases. The integrity of the cases will be demonstrated by the completion of a test program. Three cases will be hydrotested to failure; three cases will be loaded with PBAA propellant and statically fired; and the remaining case will be loaded with inert solid propellant for static structural tests. The techniques of fabrication and control criteria will be established within the development of several stub length cases. When the variables have been defined, such as strip tension, mandrel insulation properties, and related braze-time-temperature elements, the full length TU-193 cases will be wrapped. All tooling fixtures and handling equipment have been designed and procured. These, along with the materials and facilities, will be

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available for tool tryout the first part of January 1962. Considerable development effort has been accomplished in the areas of improved coil design and the related selection of the induction heating equipment, controls, and mandrel insulation. This effort should be reflected in reduced stub length case work prior to the fabrication of the full length TU-193 case.

III. WEAPON FIRE CONTROL

SECTION A - GENERAL

1-1314. AN APPROACH TO EQUIPMENT COOLING PROBLEMS IN AN ORBITAL SPACE VEHICLE. Jay S. Tupper. United Aircraft Corp. Hamilton Standard Div., No. 87B. (For Presentation at the Meeting of the Society of Automotive Engineers, Inc., 29 Sept.-4 Oct. 1958, Los Angeles. 17p. A61-10364.

A number of refrigeration systems for satellite equipment cooling are considered. Criteria used in the analysis were performance, reliability of 99.9%, lowest weight consistent with performance and reliability, ground handling characteristics, and initial and maintenance costs. Mechanical systems are too heavy for consideration. The most promising systems are the separate and integral storage systems where the stored refrigerants are fed to heat exchangers for cooling. In the separate storage systems, the refrigerants are stored in separate tanks and pressure-fed to the exchangers. Integral storage eliminates a pressure source. It is recommended that first consideration be given to the separate storage system on the basis of comparable complexity and weight savings. However, for some installations the integral storage system might be preferable.

1-1315. COMPARISON OF INFRARED TRACKING SYSTEMS. Alan R. Gedance. J. Optical Soc. Amer., vol. 51, no. 10, p. 1127-30.

This paper compares the rotating-reticle infrared tracking system with two variants of the conical-scan system. It is shown that the accuracy of the rotating reticle system is inherently limited by the size of the target image, and that the conical-scan systems have no similar limitation. For target acquisition, however, the rotating-reticle system is found to be superior. The complementary nature of the systems suggests that system performance could be optimized by dividing target acquisition and tracking into two separate tasks.

1-1316. DEVELOPMENT OF SILICON INFRARED OPTICAL COMPONENTS (TRANSMITTING WINDOWS). Robert L. Cole, Gene Mitchell and John Hicks. Final report, 1 Nov. 1958-25 Aug. 1960. Texas Instruments, Inc., Dallas. Semiconductor-Components Div., AMC rept. no. 60-7-719. Dec. 1960. 211p. illus. Contract: AF 33(600)38085. Proj. 7-719. 42 refs. A61-3958.

Silicon plates up to 12 in. in diameter by 1 in. thick and silicon hemispherical domes up to 8-1/2 in. in diameter by 1/4 in. thick can be economically cast or segmented for use as infrared transmitting windows. The optical transmission of nuclear reactor irradiated silicon showed some improvement for limited wavelengths. A form of shell casting in which molten silicon freezes to a rotating silicon-carbided graphite mandrel has been developed as a feasible and economical process to produce large size silicon domes and plates. Silicon may be joined with appropriate epoxy adhesive to produce suitable size mosaic structures. Plates 12 in. in diameter by 5/8 in. thick and domes 7-1/2 in. in diameter by 1/4 in. thick have been successfully produced. Size is limited by ability to fabricate suitable bonding fixtures. For the sizes and shapes specified in the contract, casting is the more useful and economical process to use. Silicon may be vapor deposited into 4 in. domes with a significant reduction in the

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absorption at 9 microns. Because of fabrication difficulties and a reduction in transmission between 4-8 microns, vapor deposition, as compared to cast silicon, is not presently a feasible production process. The strength of cast and thermally deformed silicon is similar to the value obtained on grown silicon material. Typical values of Modulus of Elasticity and Rupture are 26,000,000 psi and 23,000 psi respectively. A significant increase in the resistivity of silicon may be realized after irradiation. Little effect was found on the Silicon Monoxide coating before and after irradiation. Irradiating low-resistivity silicon decreases the silicon absorption coefficient the greatest in the 5-6 micron range. Some of the irradiation-induced defects which reduce the room temperature absorption coefficient are annealed out at temperatures about 400°C.

1-1317. FORCED CYCLED COOLING OF THERMAL DETECTORS. E. Speyer and E. Brigmanis. J. Optical Soc. Amer., vol. 51, no. 12, Dec. 1961, p. 1417-21.

The operation of a thermal detector may be considered as a two-part cycle: a) the rise time, or irradiation period, during which the signal flux is falling on the detector and heating it, and b) the decay time, or recovery period, during which the detector is cooling because it is in the shadow of the chopping blade. By cooling the chopping blade, the recovery time of a thermal detector can be reduced to a negligible fraction of the chopping cycle. The possible gains in chopping frequency and responsivity are analysed and calculated for the case of square-wave chopping. Disadvantages, such as distortion of the detector output waveform, are also analysed. The practical utility of forced-cycled-cooling is dubious because it is less convenient to place a refrigerated chopper blade near the thermal detector than to use a refrigerated solid-state detector. In general, the latter will also be faster than the thermal detector, so that inconveniently low chopping frequencies are unnecessary. However, if a thermal detector is used and a moderate increase in detectivity or chopping frequency is significant, then this new technique merits consideration.

1-1318. INFRARED DETECTORS. Bernard Kovit, ed. Space/Aeronautics, vol. 36, no. 4, Nov. 1961, p. 105-23.

This is a survey article with discussions of several facets of infrared detectors. The first part of the article is a summary of basic data about detectors, development programs, and new materials. Some of the specific topics are: point detectors, imaging detectors, new semiconductor materials, improvement in detectivity of detectors, and a generalized discussion of some of the uses to which the detectors are put. The second portion of the article deals with developments in quantum detectors. In quantum detectors, the absorbed photon of energy causes a change in the state of electron distribution and a measure of this change is used for detection. Characteristics of several different types of quantum detectors are given. Detectivity of these detectors at varying wavelengths of radiation is presented graphically. Included are detectors using photoconductive lead salts, indium antimonide, impurity activated germanium, germanium-silicon + gold or zinc, and miscellaneous types of photoconductive and photovoltaic detectors. The third section is devoted to imaging-tube detectors. One advantage of the IR camera tube is its all electronic scan; however, it is limited in field of view. This tube can make highly efficient use of scene radiation at tremendous data rates. High data rates are desirable for human observers, since the illusion of continuous motion in the image

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can be generated without flicker, and there is no need for an intermediate storage mechanism. However, transmission power requirements can be prohibitive. The main elements of the IR camera tube are the photosurface or target, and electron beam gun and electron optics to control the electron beam. Copper-doped germanium and gold-doped silicon have been used as targets in IR camera tubes. The germanium and silicon are thin crystal wafers ground to optical flatness. Some developments of this type of detector tube, primarily by General Electric, are outlined. Some of the problems encountered in developing these tubes and detector circuits are discussed. The fourth section is devoted to thermal detectors. Thermal detectors surpass photodetectors where constant response to different wavelengths is most desirable, as in instrumentation for analysing the spectral characteristics of emitted, transmitted or reflected IR radiation. Thermal detectors are more sensitive below incandescence than uncooled photodetectors. Cooled photodetectors have higher sensitivity in the target temperature region from below ambient to incandescence; even so, the thermal detector may be the better choice because no cooling system is needed. Several types of thermal detector are discussed: the pneumatic cell, dependent upon a pressure change in a sealed chamber; the thermoelectric cell, using the change in temperature to generate a current; and the

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metallic or thermistor bolometer detector, measuring the change of resistance with change in temperature of a metal or thermistor. Detailed characteristics of these detectors are mentioned in the text and presented in tables. A final table presents some of the applications of available infrared detectors.

1-1319. INFRARED RADIOMETRIC INSTRUMENTS ON TIROS II.
R. W. Astheimer, R. DeWaard, and E. A. Jackson.
J. Optical Soc. Amer., vol. 51, no. 12, Dec. 1961, p. 1386-93.

This paper describes the infrared instrumentation in the TIROS II weather reconnaissance satellite. A five-channel ac radiometer is mounted at 45° to the satellite spin axis. In order to obtain radiation measurements independent of satellite temperature, an optical chopping system is used which utilizes the near-zero radiation from space as a reference. These five radiometers have coincident 5° X 5° instantaneous fields of view which scan arcs over the earth's surface as the satellite spins at 10 rpm. The five channels are filtered to respond to different spectral regions in the visual and infrared which are of meteorological significance. A two-channel, wide-angle, unchopped radiometer is mounted parallel to the spin axis and sees a 50° circular field of view which progresses slowly over the earth's surface with the orbital motion of the satellite. This radiometer uses two thin thermistor disks mounted at the apex of two reflecting cones and coated black and white, respectively. These radiometers measure the solar reflection and total emission of the earth. A third infrared device having a small angular field of view normal to the satellite spin axis

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produces reference pulses as it crosses the earth's horizon. This sensor provides information to determine the inclination of the spin axis and the spin rotation rate.

1-1320. INFRARED SENSORS STABILIZE SPACECRAFT. Military Systems Design, vol. 5, no. 3, May-June 1961, p. 18-19.

A means for keeping the Mercury spacecraft horizontal with respect to the earth is required to prevent any rolling or pitching motion of the vehicle which would shift the field of view of the periscope through which the astronaut makes observation of the earth. The article describes the infrared sensors which are used to detect pitch and roll errors and provide a signal to correction devices.

1-1321. METHOD FOR THE COMPLETE DESCRIPTION OF INFRARED SKY BACKGROUNDS. Herman G. Eldering. J. Optical Soc. Amer., vol. 51, no. 12, Dec. 1961, p. 1424-9.

The use of joint probability densities are examined as a method for the complete description of background. The requirements for the complete description lead to an infinite dimensional analysis of background. The relationships between joint probability densities, the autocorrelation function and the Wiener spectra are explored to obtain some insight into the nature of background from measured Wiener spectra. Techniques for theoretical and experimental determination of probability of detection and probability of false alarm are considered. The joint probability method is capable of providing a complete statistical description background. The method does not lend itself to experimental determination of the complete background problem directly because of the amount of data and computing required. However, it shows the relation between spatial discrimination techniques and spatial frequency techniques. It also establishes a maximum degree of complexity of the description problem. Further study will probably reduce the degree of complexity and provide better insights into optimum detection techniques; this can be obtained from the joint probability description by the use of decision theory.

1-1322. A SELECTED BIBLIOGRAPHY ON INFRARED TECHNIQUES AND APPLICATIONS. William L. Wolfe. Proceedings of the Institute of Radio Engineers (IRE), Sept. 1959, Section 6, p. 1647-9.

The title describes the contents.

1-1323. SPECIAL TYPE OF DOUBLE-LAYER ANTIREFLECTION COATING FOR INFRARED OPTICAL MATERIALS WITH HIGH REFRACTIVE INDICES. J. T. Cox. J. Optical Soc. Amer., vol. 51, no. 12, Dec. 1961, p. 1406-21.

A special type of double-layer antireflection coating for infrared optical materials is described. Two types of coating are described. One consists of MgF_2 + ZnS on both sides on a Si plate with the ZnS layer on the outside; the other consists of MgF_2+Ge coated on Ge. These coatings have two unusual features: the total optical thickness of the double layer is less than one-quarter wavelength, and the film with the higher index of refraction is on the outside. The reduction in reflectance in the low reflecting region is similar to that of a single-layer coating. Measured values of transmittance are given for coatings on Si and Ge. The coatings are very durable.

1-1324. STANDARDIZED INDIUM ANTIMONIDE INFRARED DETECTING CELL PROGRAM. Fourth Interim Report, 13 Aug.-13 Nov. 1960. C. H. Sutcliffe. Philco Corp. Lansdale Div., Lansdale, Pa., Philco No. H-227 (Formerly F-3420). 12p. Contract: AF 33(600)-40090. AD 249 226. A61-4061.

Prototype jigs, fixtures, and equipment are being constructed and evaluated for incorporation into the pilot line that will be established for the production of indium antimonide photodetectors. Many detectors have been fabricated with developmental fixtures as well as by hand techniques. These detectors have been subjected to various environmental tests and measurements. Extremely high detectivities have been achieved in isolated instances and a careful study of the fabrication process has been instituted to specify the critical parameters.

1-1325. TIROS II RADIATION EXPERIMENT AND ITS PHYSICAL SIGNIFICANCE. R. A. Hanel and D. Q. Wark. J. Optical Soc. Amer., vol. 51, no. 12, Dec. 1961, p. 1394-9.

The meteorological satellite TIROS II carries a five-channel radiometer which scans the earth by rotation of the satellite. Two channels are sensitive to sunlight reflected from the earth, and three are responsive to terrestrial infrared emission. The effect of the optical properties upon the measurements is indicated. Calculations, using model atmospheres, show the sources of outgoing terrestrial radiation and limb-darkening effects for two of the channels. A map of the radiation received by the channel sensitive in the window region (8-12 microns) is compared with a conventional weather chart. The correlation is good and shows the intimate relation between the weather and upward radiation. Features which are not adequately revealed by conventional, surface-weather charts show clearly in maps constructed from TIROS II data.